THE DISTRIBUTION OF BRYOPHYTES IN THE FOREST OF SOIGNES (SOUTH OF BRUSSELS, BELGIUM)

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with the collaboration of A. Empain

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(south of Brussels, Belgium)

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Cover illustration: *Fissidens incurvus*, common in the forest of Soignes, in Belgium otherwise only common in the Mosan district (del. O. Van de Kerckhove).

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Summaries

Summary. – A complete bryological inventory of the forest of Soignes (Flanders, Wallonia and Brussels Capital Region) was performed in order to provide the bases of an ecological management of the area targeted on the preservation of the most interesting bryophyte assemblages. In total 257 bryophyte species were recorded in 71 (1 x 1) km^2 grid-squares. Two species belong to the European red list of bryophytes, 20 are rare at regional and national scale, 30 are new to the area and 35 species formerly recorded were not refound. Circa one third of the species have a relative frequency lower than 5%. The forest of Soignes is indeed mainly a plantation of beech on loamy soils, very poor in bryophytes. The species richest areas are restricted to certain particular habitats, such as sandy outcrops, paths ridges, peaty areas and relictual alluvial woods. The conservation of the bryoflora in the forest of Soignes should thus be based on a targeted management of these habitats, including the stop of the spreading of calcareous gravel on the paths. This latter practice leads to the increase of pH from 4.5 to 8 with the consequent disappearence of the acidophilous bryophytes of this habitat, e.g. *Fossombronia wondraczekii* or *Scapania curta*, in favour of basophilous bryophytes formely fairly rare in the area such as *Cratoneuron filicinum*. The mowing of former wet heath led to a drastic increase of the herbaceous layer dominated by *Molinia caerulea*, to the detriment of the heath and characteristic bryophytes such as *Sphagnum flexuosum* and *Gymnocolea inflata*. Finally senescent trees with eutrophic bark such as the elder in the humid valleys should be conserved.

Key words: forest of Soignes, forest bryophytes, forest ecological management, Brussels, Belgium.

Samenvatting. – Een complete bryologische inventarisatie van het Zoniënwoud (Vlaanderen, Wallonië en het Brussels Hoofdstedelijk gewest) werd gemaakt. Deze kan als basis dienen voor een ecologisch beheer van het gebied, met als doel het behoud van de meest interessante bryologische groeiplaatsen. In totaal werden 257 verschillende mossoorten aangetroffen in 71 (1 x 1) km^2-hokken. Twee soorten behoren tot de Europese Rode Lijst van bryofyten, 20 soorten zijn zeldzaam op regionale en nationale schaal, 30 soorten zijn nieuw voor het gebied en 35 soorten die eertijds werden gesignaleerd, heeft men niet meer kunnen terugvinden. Ongeveer een derde van de soorten heeft een relatieve frequentie van minder dan 5%. Het Zoniënwoud is hoofdzakelijk een aanplanting van beuk op lemige bodem, die zeer mossen-arm is. De soortenrijkste gebieden zijn beperkt tot een klein aantal habitats, zoals dagzomende zanden, padranden, veenachtige gebieden en relicten van alluviale bossen. Het behoud van de bryoflora in het Zoniënwoud zou dus moeten gebaseerd zijn op een doelgericht beheer van deze habitats. Zo zou een halt moeten worden toegeroepen aan de bedekking de paden met dolomiet. Dit veroorzaakt een stijging van de pH van 4,5 naar 8. Hierdoor verdwijnen acidofiele pioniersmossen zoals *Fossombronia wondraczekii* of *Scapania curta* ten gunste van de basofiele bryofyten zoals *Cratoneuron filicinum*, die vroeger tamelijk zeldzaam in het gebied waren. Maaien van de natte heide leidde tot een drastische toename van de kruidlaag gedomineerd door *Molinia caerulea* en ten nadele van de heide en zijn karakteristieke bryofyten zoals *Sphagnum flexuosum* en *Gymnocolea inflata*. Het plaggen van de veenachtige gebieden zou daarom begunstigd moeten worden in plaats van deze te maaien. Tenslotte zouden oude bomen en struiken met een eutrofe bast zoals Vlier in de vochtige valleien moeten bewaard blijven.

Résumé. – Un inventaire bryologique complet de la forêt de Soignes a été conduit afin d'apporter les bases d'une gestion écologique orientée vers la conservation des cortèges de bryophytes les plus remarquables. Un total de 257 espèces ont été inventoriées dans les 71 carrés de 1 x 1 km. Deux espèces figurent sur la liste rouge des bryophytes européennes, 20 sont rares à l'échelle régionale et nationale, 30 sont nouvelles pour la région et 35 espèces autrefois signalées n'ont pas été retrouvées. Environ un tiers des espèces ont une fréquence relative inférieure à 5%. La plus grande partie de la forêt de Soignes correspond en effet à une plantation de hêtres sur sol limoneux, très pauvre en bryophytes. Les secteurs les plus riches en bryophytes sont localisés dans quelques habitats particuliers, tels que les affleurements sableux, les ornières des sentiers, les secteurs tourbeux et les forêts alluviales relictuelles. La conservation de la bryoflore doit donc passer par une gestion orientée de ces secteurs. Ceci comprend l'arrêt de l'épandage de graviers calcaires sur les sentiers conduisant à l'augmentation du pH de 4,5 à 8 avec disparition des acidophiles pionnières caractéristiques de cet habitat, tels *Fossombronia wondraczekii* et *Scapania curta*, au profit d'espèces basophiles initialement rares dans la région tel *Cratoneuron filicinum*. Le fauchage d'une lande humide a provoqué l'augmentation spectaculaire du tapis herbacé dominé par *Molinia caerulea* au détriment de la bruyère et de ses bryophytes caractéristiques tels *Sphagnum flexuosum* et *Gymnocolea inflata*. L'étrepage des zones tourbeuses est à préférer à leur fauchage. Enfin, les arbres sénescents à écorce eutrophe comme le sureau dans les fonds de vallées doivent être épargnés.

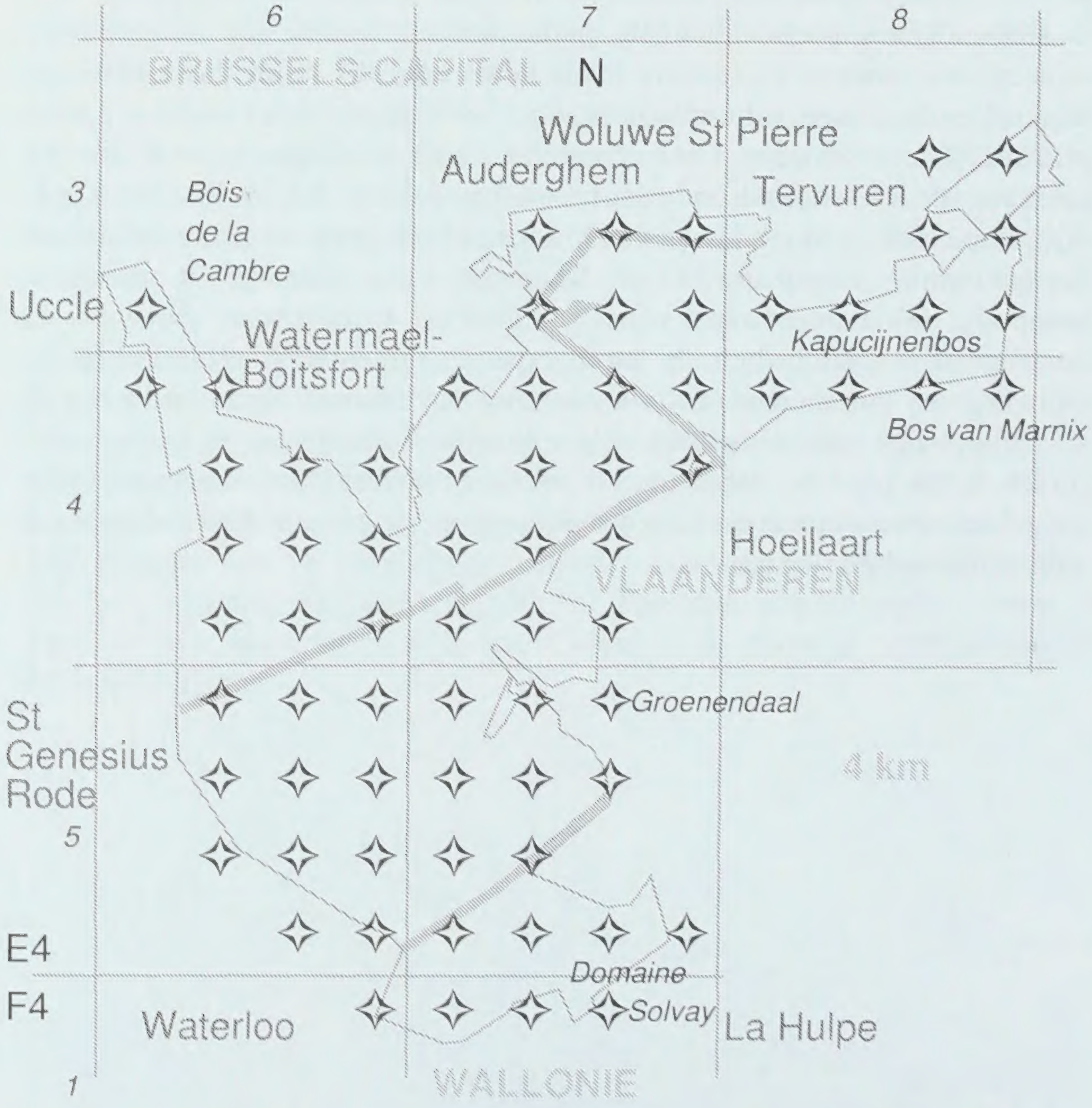

Figure 1. Map of the study area, with grid used for species mapping.

1 Introduction

The Forest of Soignes is probably one of the most impressive beechwoods of Belgium, mainly because of its 200-250 years old beech with their very long and straight boles. Very close to Brussels, it is also definitely one of the most popular forests of the country. Because of its numerous ponds, calcareous sandy slopes and its bogs, this forest proved to be very interesting from a floristic viewpoint (Delvosalle & Vanden Berghen 1959, Noirfalise & Dethioux 1977, Godefroid 1995). Ancient bryological surveys, mentioning such species as *Reboulia hemisphaerica*, *Antitrichia curtipendula*, *Ditrichum pallidum*, *Physcomitrium eurystomum* and *P. sphaericum*, demonstrated the great bryological interest of the area (Delogne & Durand 1883, Demaret 1937, Heinemann & Vanden Berghen 1943). More recently, two of us surveyed the area at the beginning of the eighties and discovered interesting species such as *Fissidens pusillus*, *Rhynchostegiella curviseta* and *Calypogeia azurea* (Sotiaux & Sotiaux, unpublished data). In 1997 a survey of the bryoflora of the Brussels Capital Region resulted in the discovery of the very rare *Ephemerum stellatum* in the forested part of the Region (Vanderpoorten 1997). Despite the great interest of these recent bryological discoveries, no recent exhaustive bryological study had yet been conducted in the area. It was consequently very difficult to integrate the bryophyte flora in the management programmes currently in progress. These management plans take the ecological aspect of the forest more into account by diversifying the plantations and by designating and managing protected areas of ecological interest. This paper aims at providing the bases for an ecological management of the area targeted on the preservation of the most interesting bryophyte assemblages. To this end, a complete inventory of the bryophyte flora of the area, a detailed mapping of the bryophyte species and an assessment of their frequency were performed. The extent of the change of the bryophyte flora since the previous bryological surveys and the causes of these floristic changes were evaluated. Finally we propose management measures to protect the most interesting bryophyte assemblages.

2 Study area

2.1 Physical characteristics

The Forest of Soignes covers 4380 ha and is located southeast of Brussels (fig. 1). The area has an undulating relief, altitude ranges from 56 to 130 m. Rainfalls occur throughout the year for about 196 days, mean annual rainfall reaches 800 mm (Heinemann & Vanden Berghen 1943).

The most superficial geological layer, almost continuous but with a depth varying from few cm to 12 m, is constituted of Quaternary loess. Under the loess lie Tertiary layers composed of clay (Asschien) and of sands (e.g. the Ledien and the Bruxellien) (Heinemann & Vanden Berghen 1943) (fig. 2). Bruxellien outcrops of calcareous sands occur in the deep valleys.

The usual profile on loess, constituted under the influence of the climate and the post glacial forest vegetation, is a leached brown soil with a strongly compacted layer, a relic of the glacial periods, called fragipan. It is characterized by a leached A layer and a textural B layer with accumulation of clay. A hydromorphous variant of the leached brown soils is characterized by the appearance of a gley in the textural B layer. It occurs where the hydrological conditions are less favourable due to a clayey layer, for example at the ponds of the Rouge-Cloître. Under the monoculture of beeches, the loamy soils are degraded to podsolic soils with a strongly spotted B layer. The upper parts of the profile present characteristic features of a neo-podsol: formation of a thick layer of holorganic mor and destruction of the underlying copromull. The colour of the latter becomes grey, its structure decreases, the sesquioxides are leached and biological activity is reduced (Galoux 1953). On some outcropping sand layers appear brownish podsolic soils or even podsols characterized by their humic and/or ferric B layer. Three main kinds of sandy soils are to be found in the forest: purely sandy and very dry soils around the ponds of the Enfants Noyes or in the valley of the Vuilbeek, sandy loess soils at the Rouge-Cloître, and sandy loess soils with a strongly spotted textural B layer around the ponds of the Ganzepootvijver in Groenendaal. Locally, peaty soils with more than 30% organic matter to a depth of at least 30 cm can be found in the marshy parts of the valleys, e.g. at the Vuilbeek or in Tervuren (Baeyens 1959, Louis 1959).

Due to the presence of two clayey layers – the first under the deepest valleys, the second on the elevated plateaus (fig. 2) - two distinct watertables are found. Their waters are rich in dissolved minerals, with a pH of ca. 7.3 and with 65.6 mg/l of

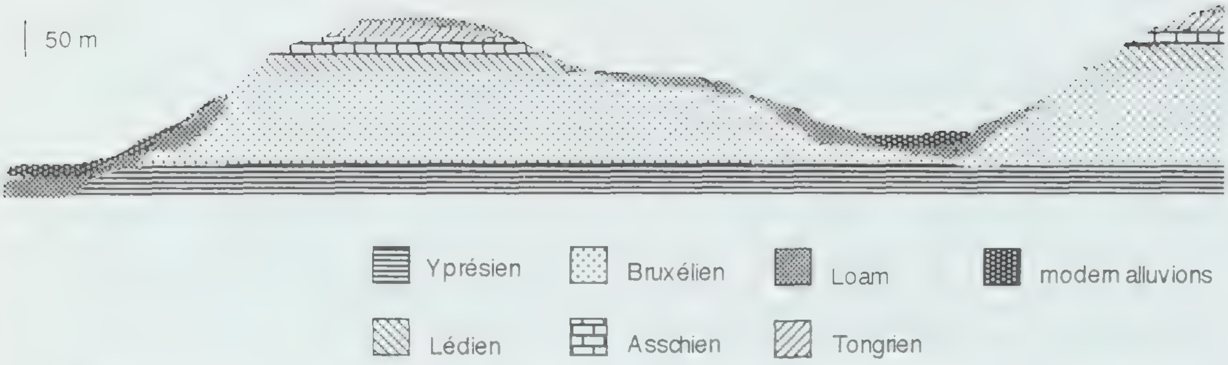

Figure 2. Geological diagram of the forest of Soignes (Redrawn from Massart 1923).

Ca^{++}, and are of good quality (Inst. Gest. Brux. Env. 1994) i.e. with average annual concentrations of ammonium inferior to 50 Fg/l. The first watertable is the most important and feeds the springs in the valleys. No rivulet has its spring at the highest extremity of the valleys but always further downstream so that the higher part of the valleys is dry. These valleys were thus not formed by the current rivulets but date from more ancient geological times (Massart 1920). Many of them are at least partly canalized. The second water table is less important . It is only revealed by temporary ponds when the loamy layer is not too deep, for example the ditches of the Welriekende with a marsh vegetation that has nowadays disappeared (Sander-Pierron 1905). Many other ponds were created by the accumulation of waters in the deepest parts of the ravines. This is for example the case for the ponds of the Enfants-Noyés in Watermael-Boitsfort. These ponds were already present on a map of 1659, were dried-up in 1810 and restored at the beginning of the century. Similarly, the Grandes Flosses (flosses being an ancient Flemish name given to small ponds) consisted of three ponds upstream of the Rouge-Cloître but do no longer exist. The Petites Flosses, on the other side of the chaussée du Mont St Jean, are currently represented by two more or less subsisting ponds (Cosyn 1981).

2.2 History

The Forest of Soignes is currently one of the last surviving evidences of the large forest anciently covering Brabant: the Carbonaria sylva of the Romans that formerly covered Picardie, Artois, Flanders, Hainaut and Brabant. It was the hunting domain of the dukes of Brabant at the beginning of the second millenary (Vleminck 1958). As the largest trees were regularly exploited during the periods of indigence of the duchy, the forest was very rich in "wild apple-trees and non valuable shrubs" (Stevens & Van Der Swaelmen 1920). The first organisation of the exploitation of

(Stevens & Van Der Swaelmen 1920). The first organisation of the exploitation of the forest, regulating the annual felling, seems to have been undertaken in the sixteenth century under the reign of Charles Quint. According to the tapestries hanging in the museum of the Louvre in Paris, the forest was composed then of beech, oak, birch, willow, alder, wild-cherry tree, chestnut-tree, ash, juniper-tree, holly, hawthorn, with a herbaceous layer rich in *Rubus* species, *Cytisus scoparius, Hedera helix, Bryonia dioica, Solanum dulcamara, Lonicera periclymenum, Tamus communis, Humulus lupulus, Clematis vitalba* and different ferns (Thoen 1965). Under the reign of Louis XIV, after many wars, the country was given to Austria in 1714. Many fires damaged the domain and, in 1786, the forest was said to be "clear like an orchard" (Stevens & Van Der Swaelmen 1920). The successor to Marie-Therese wanted to sell the forest to private persons who would have reclaimed the forest for construction. However, the private council emphasized that, in the public's interest, the State should conserve certain properties. The forest was thus replanted during the last years of the Austrian occupation from 1788 onwards, especially with beech and oak but also with hornbeam in the humid valleys. Under the first republic, after the annexation by France, clear felling was commonly undertaken. Under the Dutch government, the management of the forest was given to the Dutch General Society in 1815. When King Leopold I repurchased the domain in 1842, only 4300 ha remained of the 12000 ha in 1842 (Stevens & Van Der Swaelmen 1920). Some waste lands were then planted and form the current Bois des Capucins. In 1861, the bois de la Cambre was given to the city of Brussels (Stevens & Van Der Swaelmen 1920). Finally, the area of the current arboretum of Tervuren was given by Leopold II to the state. The plantation of the arboretum started in 1902. The regionalisation of Belgium in 1989 divided the forest in three administrative entities belonging to the Brussels Capital, Flemish and Walloon Regions.

2.3 Forestry and management

The Forest of Soignes is a suburban forest, its management must reconcile timber production, nature conservation and recreation. Due to its proximity to Brussels, it has been a forest under the strong pressure of the public for a long time. For example a walking guide was already published by Stevens & Van Der Swaelmen in 1923. The public is especially concentrated in the most interesting ecological areas such as the old abbey of the Rouge-Cloître. Unfortunately, the public has been authorized to wander everywhere in the area belonging to the Brussels Capital Region (1694 ha of the whole forest). This led to the degradation of vegetation, the erosion of slopes and the compacting of loam in these places. Therefore, paths have been improved by spreading white calcareous gravel to concentrate people on them. Nature reserves were also recently established. They are enclosed to protect them from disturbance.

The forest revolution is nowadays 200-250 years. The beech are consequently too old to regenerate naturally. The former methods, clear felling with conservation of the finest seeding trees or the progressive felling of clusters of trees (Galoux 1959), which are linked to the natural regeneration, were therefore renounced in favour of clear felling followed by plantations. In the Brussels Capital Region, the soil is tilled to a depth of 50 cm to break the upper compacted layer. The trees are mechanically planted along lines 2.5 m apart and the plantations are fertilized. The plantations have currently become more diversified because beech is not the natural dominant tree of the Forest of Soignes. As indicated by Delvosalle & Vanden Berghen (1959) the Forest of Soignes can definitely not be qualified as "*Fagetum*" (Delevoy 1941). Its horizontal roots cannot break the fragipan so that they remain in the most superficial soil layers and the trees are blown over during storms, e.g. those of 1991 that destroyed 400 ha of the forest. Pines are no longer planted, but they were frequently planted in the past, especially in sandy areas covered by heaths. An example is found at the Fond des Bouleaux, a former very open birch wood covered by *Calluna vulgaris* and *Vaccinium myrtillus* (Stevens & Van Der Swaelmen 1920).

3 Methods

Seventy-one km² of the Forest of Soignes in its large conception, including the Bois de la Cambre, the Domaine Solvay, the Bois des Capucins and the arboretum of Tervuren, were bryologically surveyed from 1996 to 1998. The IFBL grid (Van Rompaey & Delvosalle 1978) was used. The parts of the Bois de Marnix included within a square concerning the Forest of Soignes were also studied. Unpublished data recorded by two of us between 1980 and 1986 and data from recent bryological surveys (Sotiaux & Bruynseels 1985, Vanderpoorten 1997, Stieperaere & Hoffmann 1998) were included.

The bryophytes formerly collected in the area and deposited at BR were checked. Nomenclature for the phytogeographical districts follows Lambinon *et al.* (1992). The nomenclature of the mosses follows Corley *et al.* (1981) and Corley & Crundwell (1991). Nevertheless, Touw & Rubers (1989) were followed in accepting the synonymy of *Didymodon vinealis* and *D. insulanus*, of *Plagiothecium succulentum* and *P. nemorale*, of *Pottia intermedia* and *P. truncata*, and of *Leucobryum glaucum* and *L. juniperoideum*. *Tortula calcicolens* was not distinguished from *T. ruralis*. The specimens of *Amblystegium* with narrow leaf bases, lamina cells 3-4:1, flexuous costa ending in the apex and less than 40 µm wide at the leaf base, were named *varium* following Smith (1978) and Crum & Anderson (1981) but should be named *tenax* according to Frey *et al.* (1995). The nomenclature for liverworts follows Grolle (1983) except the genus *Chiloscyphus* where *C. pallescens* is considered a synonym of *C. polyanthos*.

The influence of the spread of calcareous gravel on the paths on the bryoflora was studied by recording the bryophyte layer by means of the Braun-Blanquet phytosociological coefficients of abundance-dominance. pH measurements of the superficial layer of soil were recorded in 13 places of 1 m² along forest paths. We used the Pehameter of Eijkelkamp. This field kit allows an assessment of the pH with a precision of one unit.

Table 1
Relative frequency of the bryophytes in the forest of Soignes

Liverworts

Aneura pinguis	14
Anthoceros agrestis	3
Blasia pusilla	7
Calypogeia arguta	4
Calypogeia azurea	4
Calypogeia fissa	69
Calypogeia muelleriana	68
Calypogeia neesiana	3
Cephalozia bicuspidata	83
Cephaloziella divaricata	46

Cephaloziella rubella	1
Chiloscyphus polyanthos	25
Conocephalum conicum	30
Diplophyllum albicans	64
Fossombronia pusilla	1
Fossombronia wondraczekii	21
Frullania dilatata	24
Gymnocolea inflata	1
Jungermannia gracillima	21
Lejeuna ulicina	11
Lepidozia reptans	75
Lophocolea bidentata	77
Lophocolea heterophylla	99
Lophocolea semiteres	3
Lophozia bicrenata	1
Lunularia cruciata	84
Marchantia polymorpha	34
Metzgeria furcata	46
Nowellia curvifolia	1
Nardia geoscyphus	10
Nardia scalaris	1
Pellia endiviifolia	56
Pellia epiphylla	84
Pellia neesiana	1
Phaeoceros laevis	6
Plagiochila asplenioides	3
Plagiochila porelloides	10
Porella platyphylla	4
Ptilidium pulcherrimum	8
Radula complanata	18
Riccardia chamedryfolia	6
Riccia bifurca	7
Riccia fluitans	11
Riccia glauca	6
Riccia sorocarpa	8
Riccia subbifurca	1
Scapania curta	4
Scapania irrigua	4
Scapania nemorea	6
Sphaerocarpos michelii	1
Sphaerocarpos texanus	6

Mosses

Aloina aloides	3
Aloina ambigua	10
Aloina rigida	1
Amblystegium riparium	55
Amblystegium serpens	97
Amblystegium tenax	3
Amblystegium varium	8
Anomodon viticulosus	14
Aphanorhegma patens	6
Atrichum undulatum	100
Atrichum tenellum	1
Aulacomnium androgynum	63
Aulacomnium palustre	1
Barbula convoluta	92
Barbula unguiculata	96
Brachythecium albicans	6
Brachythecium glareosum	13
Brachythecium mildeanum	4
Brachythecium plumosum	1
Brachythecium populeum	43
Brachtythecium rivulare	24
Brachythecium rutabulum	100
Brachythecium salebrosum	63
Brachythecium velutinum	70
Bryoerythrophyllum recurvirostrum	83
Bryum argenteum	87
Bryum barnesii	35
Bryum bicolor	15
Bryum caespiticium	11
Bryum capillare	96
Bryum gemmiferum	18
Bryum klinggraeffii	1
Bryum pallens	8
Bryum pallescens	3
Bryum pseudotriquetrum	4
Bryum rubens	20
Bryum ruderale	13
Bryum subapiculatum	3
Bryum subelegans	1
Calliergon cordifolium	1

Calliergonella cuspidata	83
Campylium calcareum	3
Campylium chrysophyllum	6
Campylopus flexuosus	41
Campylopus introflexus	79
Campylopus pyriformis	34
Ceratodon purpureus	99
Cirriphyllum piliferum	24
Climacium dendroides	3
Cratoneuron filicinum	90
Cryphaea heteromalla	20
Ctenidium molluscum	11
Dichodontium pellucidum	7
Dicranella cerviculata	1
Dicranella heteromalla	100
Dicranella rufescens	41
Dicranella schreberiana	21
Dicranella staphylina	30
Dicranella varia	32
Dicranodontium denudatum	3
Dicranoweisia cirrata	97
Dicranum majus	10
Dicranum montanum	89
Dicranum scoparium	83
Dicranum tauricum	94
Didymodon fallax	38
Didymodon luridus	17
Didymodon rigidulus	27
Didymodon sinuosus	13
Didymodon tophaceus	14
Didymodon vinealis	76
Ditrichum cylindricum	52
Ditrichum heteromallum	14
Drepanocladus aduncus	13
Encalypta streptocarpa	25
Enthostodon fascicularis	3
Ephemerum serratum	8
Ephemerum stellatum	1
Eucladium verticillatum	13
Eurhynchium crassinervium	16
Eurhynchium hians	90
Eurhynchium praelongum	100
Eurhynchium pumilum	52
Eurhynchium schleicheri	20
Eurhynchium speciosum	3
Eurhynchium striatulum	3
Eurhynchium striatum	59
Fissidens adianthoides	1
Fissidens bryoides	95
Fissidens crassipes	3
Fissidens dubius	14
Fissidens exilis	3
Fissidens gracilifolius	35
Fissidens incurvus	15
Fissidens pusillus	1
Fissidens taxifolius	90
Fissidens viridulus	10
Fontinalis antipyretica	3
Funaria hygrometrica	79
Grimmia pulvinata	76
Gyroweisia tenuis	10
Herzogiella seligeri	49
Homalia trichomanoides	32
Homalothecium lutescens	11
Homalothecium sericeum	41
Hygrohypnum luridum	7
Hypnum cupressiforme	100
Hypnum jutlandicum	77
Hypnum lindbergii	11
Isothecium alopecuroides	13
Isothecium myosuroides	48
Leptobryum pyriforme	6
Leskea polycarpa	24
Leucobryum glaucum	66
Mnium hornum	100
Mnium marginatum	7
Mnium stellare	13
Neckera complanata	21
Orthodontium lineare	63
Orthotrichum affine	89
Orthotrichum anomalum	39
Orthotrichum consimile	1
Orthotrichum cupulatum	4
Orthotrichum diaphanum	93
Orthotrichum lyellii	15
Orthotrichum obtusifolium	3
Orthotrichum pallens	1
Orthotrichum pulchellum	7

Orthotrichum pumilum	4
Orthotrichum stramineum	6
Orthotrichum striatum	4
Orthotrichum tenellum	8
Phascum cuspidatum	20
Physcomitrium pyriforme	20
Plagiomnium affine	66
Plagiomnium cuspidatum	10
Plagiomnium ellipticum	3
Plagiomnium rostratum	49
Plagiomnium undulatum	85
Plagiothecium cavifolium	41
Plagiothecium curvifolium	55
Plagiothecium denticulatum	32
Plagiothecium laetum	24
Plagiothecium nemorale	69
Plagiothecium undulatum	35
Platygyrium repens	4
Pleuridium acuminatum	24
Pleuridium subulatum	14
Pleurozium schreberi	13
Pogonatum aloides	28
Pogonatum nanum	4
Pohlia annotina	11
Pohlia lescuriana	31
Pohlia lutescens	49
Pohlia melanodon	42
Pohlia nutans	87
Pohlia wahlenbergii	38
Polytrichum commune	1
Polytrichum formosum	90
Polytrichum juniperinum	10
Polytrichum piliferum	8
Pottia bryoides	3
Pottia lanceolata	1
Pottia truncata	27
Pseudephemerum nitidum	21
Pseudocrossidium hornschuchianum	37
Pseudocrossidium revolutum	4
Pseudotaxiphyllum elegans	93
Pterigynandrum filiforme	1
Pylaisia polyantha	4
Racomitrium heterostichum	1
Rhizomnium punctatum	65
Rhynchostegiella curviseta	7
Rhynchostegiella tenella	6
Rhynchostegium confertum	90
Rhynchostegium murale	73
Rhynchostegium riparioides	35
Rhytidiadelphus loreus	1
Rhytidiadelphus squarrosus	62
Schistidium apocarpum	65
Scleropodium purum	54
Sphagnum fimbriatum	1
Sphagnum flexuosum	3
Sphagnum palustre	1
Sphagnum subnitens	1
Taxiphyllum wissgrillii	3
Tetraphis pellucida	62
Thamnobryum alopecurum	17
Thuidium tamariscinum	28
Tortella tortuosa	7
Tortula intermedia	1
Tortula laevipila	3
Tortula marginata	4
Tortula muralis	94
Tortula papillosa	1
Tortula princeps	1
Tortula ruralis	23
Tortula subulata	15
Tortula virescens	7
Ulota bruchii	63
Ulota crispa	13
Ulota phyllantha	3
Warnstorfia fluitans	1
Weissia controversa	13
Zygodon conoideus	6
Zygodon viridissimus	23

4 Results and discussion

4.1 The bryophyte flora of the Forest of Soignes

Two hundred and fifty-seven species were recorded in this study (tab. 1); thirty species are new to the area (tab. 2). Thirty-five species recorded before 1980 (Demaret 1937, Delogne & Durand 1883, Heinemann & Vanden Berghen 1943) were not refound and are possibly extinct (tab. 3).

Table 2
Bryophytes new to the area

Calypogeia arguta
Cephaloziella rubella
Fossombronia pusilla
Gymnocolea inflata
Lophocolea semiteres
Nardia geoscyphus
Nowellia curvifolia
Pellia neesiana
Sphaerocarpos michelii

Atrichum tenellum
Brachythecium plumosum
Bryum klinggraeffii
Bryum pallescens
Bryum pseudotriquetrum
Bryum subapiculatum
Dicranum majus
Eurhynchium striatulum
Fissidens exilis
Orthotrichum consimile
Orthotrichum pallens
Orthotrichum striatum
Pohlia lescuriana
Pohlia lutescens
Pottia lanceolata
Pylaisia polyantha
Racomitrium heterostichum
Sphagnum fimbriatum
Tortula marginata
Tortula princeps
Ulota phyllantha

Some mosses previously recorded in the Forest of Soignes were misidentified and must be deleted from the list of the area. All the collections of *D. majus* at BR belong to *D. scoparium*, with four distinctive lamellae at the back of the nerve at the leaf apex. *Nardia geoscyphus*, recorded by Heinemann & Vanden Berghen (1943), is not known in Brabant according to Vanden Berghen (1979) and Schumacker (1985) and no collection could be found at BR. Our discovery of these two species in the Forest is therefore the first genuine record for them; they were therefore included in the list of species new to the area.

The collection of *Campylopus brevipilus* (De Zuttere & Schumacker 1984) should be referred to *C. introflexus* (specimen revised by H. Greven in 1991 and A. Vanderpoorten in 1997) because it has a single dorsal stereid layer. The collection of *Amblystegium subtile* should be referred to *A. serpens*. *Cephalozia connivens* recorded in Auderghem (herb. *Mansion*) is a wrongly determined collection of *C. bicuspidata* (revised by R. Schumacker in 1987). *Gymnostomum aeruginosum*, which figures in the list of Demaret (1937), is not known in Brabant according to Demaret & Castagne (1961) and Vanden Berghen (1979); no samples were found at BR and these data are consequently excluded. All the Belgian collections of *Philonotis rigida* were misidentified and mostly refer to *P. arnellii* (Raeymaekers 1981), although no sample of the latter from the study area was found at BR. *Weissia brachycarpa* and *W. controversa* were probably confused by Demaret (1937); no collection of the former has been found at BR where the collections of the latter are numerous. The only collection of *Bryum intermedium* from the area at BR (*Gravet* s.n., Bois de la Cambre, 14 août 1874) has the cilia of the endostome clearly appendiculate and has a more or less mucronate calyptra. The endostome cilia of *B. intermedium* are nodulose or rarely appendiculate according to Demaret (1993), Smith (1978) and Nyholm (1993). According to this conception, the collection must refer to *B. pallescens*, although the material was revised by F. Demaret who confirmed *B. intermedium*. Touw & Rubers (1989) claim that *B. intermedium* can have the cilia of the endostome appendiculate. Here, everything is a question of interpretation of the mucronate feature of the calyptra and of the mouth shape of the capsule. We think that the collection is closer to *B. pallescens*.

Some collections were not found at BR. Many of them belong to difficult taxa and the material at BR was often ill-named (*Archidium alternifolium*, *Thuidium delicatulum*, *Ditrichum pusillum*); others, for example *Acaulon muticum*, are not forest mosses, so that these data must be carefully interpreted and are shown in the list with an asterisk. The material of *Jungermannia hyalina* of Sougnez (1977) from the arboretum of Tervuren, was not refound at the herbarium of the Faculté Agronomique de Gembloux. The record is considered as doubtful because of the ecology of the sampling site (an acidic grassland dominated by *Festuca filiformis*, *Nardus stricta* and *Calluna vulgaris* (column 10, tab. 1 in Sougnez 1977) and the data were not included in the list.

4.2 The bryophyte richness of the Forest of Soignes

With 257 bryophyte species recorded on 4300 ha, the Forest of Soignes belongs to the richest forests of the Benelux and Northern France. For example, the forest of Fontainebleau has ca. 450 species on 25000 ha (Doignon 1947) and in the forest of

Table 3
Bryophytes formerly recorded in the forest of Soignes and not rediscovered in the course of this study

(* no collection at BR)

Bazzania trilobata	Delogne & Durand (1883)
Blepharostoma trichophyllum	Delogne & Durand (1883)
Diplophyllum obtusifolium	Demaret (1937)
Frullania fragilifolia	Demaret (1937)
*Kurzia pauciflora**	Heinemann & Vanden Berghen (1943)
Lophozia incisa	Demaret (1937)
Lophozia ventricosa	Demaret (1937)
Reboulia hemisphaerica	Demaret (1937)
Riccia cavernosa	Delogne & Durand (1883)
Riccia huebeneriana	Heinemann & Vanden Berghen (1943)
Acaulon muticum	Delogne & Durand (1883)
Antitrichia curtipendula	Demaret (1937)
*Archidium alternifolium**	Demaret (1937)
Bartramia pomiformis	Demaret (1937)
Bryum radiculosum	Demaret (1937)
Buxbaumia aphylla	Demaret (1937)
Diphyscium foliosum	Delogne & Durand (1883)
Ditrichum pallidum	Demaret (1937)
*Ditrichum pusillum**	Demaret (1937)
Grimmia crinita	Delogne & Durand (1883)
Hylocomium splendens	Sougnez (1977)
Neckera crispa	Demaret (1937)
*Neckera pumila**	Delogne & Durand (1883)
*Philonotis arnellii**	Demaret (1937)
Physcomitrium eurystomum	Demaret (1937)
Physcomitrium sphaericum	Delogne & Durand (1883)
Plagiomnium elatum	Delogne & Durand (1883)
Pogonatum urnigerum	Demaret (1937)
Pterogonium gracile	Demaret (1937)
Rhytidiadelphus triquetrus	Demaret (1937)
Sphagnum compactum	Demaret (1937)
Sphagnum squarrosum	Heinemann & Vanden Berghen (1943)
Thuidium abietinum	Delogne & Durand (1883)
*Thuidium delicatulum**	Delogne & Durand (1883)
Tortula cuneifolia	Demaret (1937)

of Rambouillet, 231 species (according to the nomenclature used in this paper) were recorded in a selection of study sites in the 22000 ha of the forest (Bardat 1997).
This is at first sight fairly surprising, as the Forest of Soignes is located South of the largest city of Belgium and is surrounded by a densely populated area. It is also surprising, because the Forest of Soignes does not possess natural rocky places nor habitats that are usually bryophyte-rich, such as calcareous grasslands. Most parts of the forest are very monotonous plantations of beech of the same age and the same height and without any shrub layer. Most parts of the forest possess therefore a homogeneous and rather poor bryoflora with *Pellia epiphylla, Dicranella heteromall* and *Mnium hornum* (Demaret 1938).

In fact, the bryophytic richness of the forest is due to two main factors. First, some biotopes very rich in bryophytes remain in the forest, so the species richness varies from ca 40 to 119 species/km.

- the calcareous sandy slopes with, e.g. *Plagiochila porelloides, Porella platyphylla, Homalothecium lutescens.*
- the paths of compacted acidic loam, with very rich assemblages of pioneer species such as *Dicranella rufescens, Pseudephemerum nitidum, Fossombronia wondraczekii.*
- the ancient alluvial woods rich in old elders and willows, with their characteristic epiphytic assemblages including many Orthotrichaceae.

Secondly, the bryophytic richness of the Forest of Soignes is, as its vascular flora (Godefroid 1995), artificially increased by many bryophytes not characteristic of forests, such as epilithic species (e.g. *Tortula muralis* and *T. marginata*). Also, many species characteristic of ancient woodlands, such as *Anomodon viticulosus, Brachythecium populeum, Homalia trichomanoides, Homalothecium sericeum, Rhizomnium punctatum, Taxiphyllum wissgrillii, Thamnobryum alopecurum* (Rose 1992), are found in the Forest of Soignes on concrete of the drainage network. Thus, the richness of the Forest of Soignes is partly due to the ability of the bryophytes to colonize substitution habitats after the disappearance of their natural habitats. Yet species without dispersion strategies that do not allow them to find substitution habitats, for example bog species (e.g. *Calliergon cordifolium*) or pioneer species (e.g. *Blasia pusilla*) are very rare. That is why the distribution of frequencies is asymmetrical in favour of the rare species (tab. 4). This must nevertheless be carefully interpreted because certain species, e.g. *Lophozia bicrenata, Riccia subbifurca* or *Aloina rigida*, are not characteristic of forested areas. *Racomitrium heterostichum* was also probably introduced in the area with siliceous stones and was not refound in its only site in 1997. It is very likely that many of these rare species will disappear during the following years so that the distribution of frequencies will be homogenized. This is already the case with the vascular flora, which possesses few rare species (Godefroid 1995).

Thirty-three species are included in the rare (r), threatened (t), extinct (e) and data deficient (new, rare but probably overlooked: o) species of Belgium (De Zuttere & Schumacker 1984): *Calypogeia azurea* (o), *Cephaloziella rubella* (o), *Pellia neesiana* (o), *Riccia bifurca* (r), *Aphanorhegma patens* (o), *Bryum barnesii* (o), *B. gemmiferum* (o), *B. ruderale* (o), *Cryphaea heteromalla* (r), *Dicranella staphylina* (o), *Dicranum tauricum* (o), *Didymodon sinuosus* (o), *Ditrichum cylindricum* (o), *Ephemerum serratum* (r), *Fissidens exilis* (o), *F. incurvus* (o), *F. pusillus* (e?), *F. viridulus* (o), *Orthotrichum obtusifolium* (o), *O. pulchellum* (t), *O. pumilum* (r), *O. stramineum* (t), *Platygyrium repens* (o), *Pohlia lescuriana* (o), *P. lutescens* (r), *Pottia bryoides* (r), *Pterigynandrum filiforme* (t), *Rhynchostegiella curviseta* (o), *Tortula marginata* (o), *T. princeps* (o), *T. virescens* (o), *Ulota phyllantha* (t) and *Zygodon conoideus* (t).

Table 4
Species frequencies distribution

Class of relative frequency	number of species
<5	29
5-10	15
10-25	20
25-50	14
50-75	10
>75	16

Thanks to the intensive field work carried out by some amateurs since 1984, the estimation of the frequency of many species has been improved. The following species, considered as Anew, rare but probably overlooked by De Zuttere & Schumacker (1984), are common in Belgium: *Riccia bifurca, Bryum barnesii, B. gemmiferum, B. ruderale, Dicranella staphylina, Dicranum tauricum, Ditrichum cylindricum, Ephemerum serratum, Fissidens. viridulus, Pohlia lescuriana* and *P. lutescens*. The last two are in fact inconspicuous mosses that grow frequently together on the fresh loam of dry rivulet banks or at the base of fallen trees. They can only be determined by observing their rhizoidal gemmae: although much material of these species was collected, their distinction in the field was not possible. Conversely to what was written by Demaret & Arts (1993), using the more or less shiny appearance of the plants or the thickness of the nerve at the base of the leaf to name the collections was not possible. Special attention has been paid to the epiphytes for some years, and it appears that species such as *Cryphaea heteromalla, Orthotrichum obtusifolium, O. pallens, O. pulchellum, O. pumilum* and *O. stramineum* were largely overlooked. They are present in almost all the Belgian phytogeographical districts and their frequency is much higher than their recent distribution maps suggest (De Zuttere 1992). On the other hand, *Rhynchostegiella curviseta* was considered by De Zuttere & Schumacker (1984) as rare but probably overlooked by confusion with *Amblystegium serpens*. This is, however, imrobable, as the lid of this autoecious and frequently fertile species is long rostrate and thus very different of that of the Amblystegiaceae.

The most remarkable species of the Forest of Soignes are thus the following:

Two species belonging to the European Red List of Bryophytes (ECCB 1995):

- *Ephemerum stellatum* has its only Belgian locality in the Forest of Soignes and occurs probably in less than ten localities in the world (Hill *et al.* 1994).
- *Orthotrichum consimile* was considered extinct in Europe (ECCB 1995) but was recently rediscovered in Spain and in Germany (Lewinsky *et al.* 1995, Mazimpaka *et al.* 1997). This species was discovered for the first time in Belgium in eight localities, mainly in the Ardennes and in one locality in the Forest of Soignes, growing on elder at the edge of the forest (Sotiaux *et al.* 1998).

Twenty other species rare at national or regional scale:

- *Calypogeia azurea* was known in only nine localities in the phytogeographical district "Ardennais" and one in the "Brabançon" (De Zuttere & Schumacker 1984).
- *Cephaloziella rubella* was not recorded from the phytogeographical district "Brabançon" (Schumacker 1985) but is definitely an overlooked species.
- *Lejeunea ulicina*: The Forest of Soignes is, after the valley of the river Semois, the second most important area of distribution for this hepatic otherwise very rare in Belgium. It usually grows on the boles of old trees such as oak, beech and hornbeam in the oldest parts of the forest, but it was also once found epiphyllous on a *Didymodon* species growing on concrete.
- *Nardia geoscyphus*: this boreal species is very rare in the phytogeographical district "Brabançon" and was never recorded from the Forest of Soignes (Schumacker 1985). This species was found on south-west exposed acidic sandy-loamy slopes along the Étang du Moulin, upstream from the Rouge-Cloître abbey.
- *Nowellia curvifolia*: this hepatic of decaying wood was discovered for the first time in Belgium in 1962 (Lambinon 1964) and was known from sixty-three IFBL squares in the distribution map of Schumacker (1985). At that time, the species was common in the High Ardennes, rare in the phytogeographical district "Lorrain" and very rare in the "Mosan". In 1990 this species was found for the first time north of the Sambre & Meuse in Hoeselt (Prov. Limburg) (Sotiaux et

al. 1998). This species was found on decaying wood in a humid valley in Boitsfort.

- *Pellia neesiana* was only known in one locality in the phytogeographical district "Ardennais", one in the "Brabançon" and one in the "Mosan" (De Zutterre & Schumacker 1984). This species was not rediscovered until recently but has probably been much confused with *P. epiphylla*. Since 1984, it was recorded several times in the phytogeographical district "Campinien" (Andriessen & Nagels, pers. comm.) and frequently in the Ardennes (Sotiaux & Sotiaux, unpublished data).
- *Sphaerocarpos michelii* is in Belgium at the northern limit of its distribution area and was considered as extinct in Belgium (De Zuttere & Schumacker 1984). It was recently rediscovered three times in the phytogeographical districts "Flandrien" and "Brabançon" (Stieperaere *et al.* 1988). *Sphaerocarpos michelii* was found mixed with *S. texanus* along a path in the park near the Africa Museum in Tervuren.
- *Aphanorhegma patens* was known in 21 IFBL grid-squares after 1950 (De Zuttere & Schumacker 1984).
- *Brachythecium plumosum* is common on siliceous stones or tree bases subjected to flooding, south from the Sambre et Meuse, but is very rare elsewhere in Belgium. It was found in a substitution habitat, on concrete of a drainage channel in Uccle.
- *Dicranum majus* was reported in the bryological survey of the Forest of Soignes of Demaret (1937) but these data were not included in the "Flore générale de Belgique" (Demaret & Castagne 1961), in which it was mentioned as common in the phytogeographical districts "Mosan" and "Ardennais" and very rare in the "Picardo-brabançon" (reported from Renaix, Stambruges and Fauquez). We found it on acidic humus of steep and dry slopes very often with *Leucobryum glaucum*.
- *Enthostodon fascicularis* is an annual species of bare soils and loamy grasslands that is fairly common in the phytogeographical district "Mosan" and relatively rare in the "Ardennais". It has been very rarely recorded north from the Sambre & Meuse . It was found in Tervuren, on a path in the park of the Africa Museum.
- *Eurhynchium striatulum* is very rare in Belgium outside the phytogeographical district "Mosan" where it is common on calcareous rocks. Exactly as in The Netherlands (Touw & Rubers 1989), it grows in the Forest of Soignes in a substitution habitat, on the concrete of a drainage channel.
- *Fissidens incurvus*, which is common in the phytogeographical district 'Mosan', was recorded only once in Brabant.
- *Fissidens pusillus* was known from a single Belgian locality and classified within the category of possibly extinct species (De Zuttere & Schumacker 1984) but we found it frequently in brooks with low dissolved mineral content in the Ardennes.

Its only locality in the Forest of Soignes (on a sandstone rock in a rivulet) is one of its very rare localities outside the Ardennes.

- *Platygyrium repens* was known in four Belgian localities before 1950 and in 28 after 1950 (De Zuttere & Schumacker 1984). This species, probably spreading, is common in the phytogeographical district "Mosan" but is much rarer in the other ones. It was found twice in the Forest of Soignes, on willow in a wet woodland in Watermael-Boitsfort and on elder along the ponds of Groenendaal.
- *Pterigynandrum filiforme* was recorded in the Forest of Soignes during the 19th century. It has not been rediscovered since then in the phytogeographical district "Brabançon" and is very rare in Belgium (De Zuttere *et al.* 1986). It was found on willow along the ponds of Hoeilaart.
- *Rhynchostegiella curviseta* is not rare in the Forest of Soignes on the concrete of the drainage network.
- *Rhytidiadelphus loreus* is common in the phytogeographical district "Ardennais", very rare in the "Campinien", and was several times recorded in the Forest of Soignes during the last century in Groenendaal, Auderghem, Boitsfort and La Hulpe. It seems to have disappeared from all these places but was refound in Sint-Genesius Rode on decaying wood, mixed with tall Brachytheciaceae (*Brachythecium rutabulum* and *Eurhynchium praelongum*).
- *Ulota phyllantha* was known in Belgium in three coastal localities (two recent and one ancient) and in a single locality inland (De Zuttere 1992); the Forest of Soignes is thus the fourth recent and the second very surprisingly inland Belgium locality of this suboceanic species which was found on elder in Groenendaal and on oak in a young plantation in Sint-Genesius Rode.
- *Zygodon conoideus* was only known in one ancient and five recent localities south of the Sambre et Meuse and in a single locality in the Forest of Soignes, but this collection was not refound. The last decade, one of us has frequently gathered this species south of the Sambre & Meuse and we found it four times in the Forest of Soignes, always on elder.

4.3 Suggestions concerning the management of certain sites of high bryological interest

The moss layer of the Forest of Soignes is mostly very species poor due to the very homogeneous pedological conditions. The preservation from disturbance and the ecological management of particular bryophyte rich sites, would allow the conservation of a large part of the sometimes very interesting bryophyte assemblages of the Forest of Soignes. Some sites have already become nature reserves. Because many different biotopes, like old willows, calcareous slopes, ponds, Y are involved, the five nature reserves of the Brussels Capital Region contain ca. 45% of the total bryoflora of the whole forest and ca. 25% of the rare bryophytes. By comparison, the

two reserves of the Flemish Region possess ca. 40% of the bryoflora of the whole forest but only ca. 7% of the rare species. These reserves in fact do not include the parts of the forest that are most interesting from a bryological point of view. They comprise namely the dry upper part of some loamy plateaus that are poor in interesting bryophytes. The most interesting places from a bryological point of view will be briefly described in this chapter to suggest the creation of protected areas and management practices favouring the bryophytes.
The Forest of Soignes harbours a single vegetation of wet heath at the Keienberg in Tervuren, with species such as *Aulacomnium palustre* and *Warnstorfia fluitans*. This vegetation contained in the 80's the Ericaceae *Vaccinium myrtillus* and *Calluna vulgaris* and large patches of *Sphagnum flexuosum*, whereas *Gymnocolea inflata* was found on the humid peaty soil. It is now dominated by *Molinia caerulea* and Ericaceae are restricted to the margins, probably because of mowing. *Gymnocolea inflata* was not refound whereas the sphagna, poorly developed by comparison with the luxuriant plants gathered in 1980, are restricted to small patches in the lowest part of the area.

At the Keienberg the vegetation is now obviously much drier. It is now mainly covered by bryophytes of grasslands such as *Rhytidiadelphus squarrosus*, by xerophilous xenophytic species such as *Campylopus introflexus* and by *Polytrichum commune* or *Aulacomnium palustre* (tab. 5), both fairly resistant to dessication. The latter species was reported from summer dry soils, in company of *Racomitrium lanuginosum* (Glime & Hong 1997). It is very likely that the fall of the water table has caused the change in the vegetation. This is due to pumping and to a succession of very hot and dry summers in the 1990's.

Table 5
Phytosociological records of the wet heath at the Keienberg in the Bois des Capucins

N° of the record surface (sq.m)	3 4	1 16	4 16	2 50
Sphagnum flexuosum	-	2-3	-	-
Polytrichum commune	-	1-1	1-1	5-5
Warnstorfia fluitans	5-5	1-1	-	-
Hypnum jutlandicum	-	2-2	1-1	2-2
Campylopus introflexus	-	2-3	1-1	-
Lophocolea bidentata	-	+	-	-
Pohlia nutans	-	+	-	-
Pleurozium schreberi	-	1-1	-	1-1
Aulacomnium palustre	-	-	4-4	+
Dicranum scoparium	-	-	-	2-2
Scleropodium purum	-	-	-	2-2
Rhytidiadelphus squarrosus	-	-	-	1-1

Table 6a
Influence of the spreading of calcareous gravel on paths on the bryoflora
Comparison of the bryoflora of some selected paths

1: drève de la pépinière, IFBL E4.46.44; 2: drève du comte, IFBL E4.46.44; 3: Paardendelle, IFBL E4.38.43; 4: arboretum de Tervuren, IFBL E4.58.12; 5: drève des morilles, IFBL E4.46.42; 6 bois de la Cambre, IFBL E4.36.33; 7: bois des capucins IFBL E4.48.21

Number of the sample	1	6	2	3	4	5	7
Pohlia wahlenbergii	+						
Marchantia polymorpha	3	1					
Plagiomnium undulatum	+	1					
Lunularia cruciata		2					
Brachythecium rutabulum	3	2	3				
Cratoneuron filicinum	2	3	2				
Pellia endiviifolia	1	3					
Dicranella varia	+	2					
Eurhynchium hians	+	1					
Bryum argenteum		+	+				
Ceratodon purpureus		1	1				
Calliergonella cuspidata	1	2	2		1	2	2
Pellia epiphylla				+		1	1
Riccardia chamedryfolia				+			
Ephemerum serratum				2			
Ditrichum cylindricum				1	1	1	1
Cephalozia bicuspidata				+		1	1
Jungermannia gracillima				1	1	1	1
Fossombronia wondraczekii				2	1	1	1
Rhytidiadelphus squarrosus				1	1		1
Pohlia annotina					+	+	
Scapania irrigua						+	
Nardia scalaris						+	
Atrichum undulatum							3
Dicranella rufescens							2
pH	7-8	7	8	4-5	4-5	5	4-5

Nevertheless, it is also likely that the mowing of the vegetation favours the competitive *Molinia caerulea* to the detriment of the Ericaceae and the bryophytes of wet heaths, Sphagna and small hepatics. This is corroborated by the former records of the *Polygala serpyllifolia-Nardetum* sub-association with *Molinia caerulea* in the arboretum of Tervuren (Sougnez 1977). In this grassy stage of the *Calluno-Genistetum pilosae*, the cover of the Ericaceae reached at least 10%. Bryophytes such as *Rhytidiadelphus squarrosus*, *Scleropodium purum* and *Pleurozium schreberi* were present, but also the more exacting *Hylocomium splendens*.

We suggest superficial sod-cutting as an interesting management practice, which would open the grass layer. The felling of pines 10-30 m around the heath would raise the level of the pseudo-gley. It may also create a transitional vegetation between the former wet heath and the dry pine plantations. The part that has naturally evolved to birch forest, should be maintained, as it illustrates the natural vegetation dynamics. Also the oldest stages with birch harbour interesting shade-demanding species such as *Sphagnum fimbriatum*, new to the area.

Acidic paths of compacted loam are another bryophyte-rich habitat to be preserved. Important examples are the path of the Caudael in Watermael-Boitsfort, with *Ephemerum stellatum*, the drève des Morilles in Watermael-Boitsfort, with *Scapania irrigua*, *Fossombronia wondraczekii*, *Nardia scalaris*, the path between the Hoge Toren and the Leemberg in Tervuren with *Scapania curta* and *Ditrichum heteromallum*, and the paths of the meadows in the arboretum of Tervuren, with *Blasia pusilla*, *Riccardia chamedryfolia*, *Bryum pallens*, *Ephemerum serratum* and *Fissidens exilis*.

Nowadays, calcareous gravel is spread on the paths in the three regions to concentrate the public. This very quickly raises the pH from ca. 4-5 to 7-8. At these pH levels, free calcium exists and this causes the change of the bryoflora. In fact, free calcium and magnesium are toxic for the pioneer species of compacted acidic loam, such as *Ditrichum cylindricum*, *Fossombronia wondraczekii* and *Ephemerum serratum*. Consequently these species disappear in favour of calciphilous species such as *Dicranella varia* and *Cratoneuron filicinum* (tab. 6a). *Cratoneuron filicinum* occurs now in more than 80% of the investigated grid-squares, whereas it was quite rare before 1900 (Delogne & Durand 1883). The influence of the gravel on the bryoflora extends up to three metres from the path in the forest (tab. 6b). This is due to the projection of calcareous gravel outside the path and to the run off of calcium enriched water from the paths into the forest. These results are similar, on a smaller scale, to those obtained by Ahrens (1995). He studied the spread of calcium in forests supposed to be acidified by acidic rains. The acidophytes *Lepidozia reptans*, *Pseudotaxiphyllum elegans*, *Dicranella heteromalla* and *Hypnum cupressiforme* were damaged one year after the spreading. Three years later, species belonging to the group of *Brachythecium rutabulum*, including *Amblystegium serpens*, *Barbula unguiculata* and *Bryoerythrophyllum recurvirostrum* appeared and several rare acidophilous species disappeared.

Table 6b
Influence of the putting of calcareous gravel on paths on the bryoflora
Transect drève de Lorraine, ca. 50 m South of the drève St Michel, IFBL E4.56.21

Number of record	1	2	3	4	5	6
distance from the path (m)	0	0.5	1.5	2.5	3	4.5
Bryoerythrophyllum recurvirostrum	5	4	+			
Ceratodon purpureus		+	+			
Barbula convoluta		+				
Brachythecium rutabulum		1	3	5	3	1
Hypnum cupressiforme		+		+		1
Fissidens taxifolius		+	+		+	
Bryum capillare			+			
Didymodon vinealis			+			
Brachythecium velutinum				+		
Mnium hornum				+		3
Brachythecium salebrosum				+		+
Eurhynchium praelongum					3	
Atrichum undulatum					+	+
Eurhynchium striatum					+	
Polytrichum formosum						1
Dicranella heteromalla						1
Lepidozia reptans						1
pH	8-9	8	7	5-6	5-6	4-5

To conserve the last very rich assemblages of pioneer species of bare acidic soils, the spreading of gravel should be stopped on the smallest paths and should definitely not be carried out on the last uncovered paths. The use of heavy machines should also be prohibited in the last small paths not recovered by calcareous gravel such as that between the Hoge Toren and the Leemberg. Here a very important locality of *Scapania curta* has been recently strongly damaged by such machines.

The calcareous sandy slopes are one of the most original habitats of the Forest of Soignes. They are, with the aquatic habitats, the only natural habitats of the forest where calciphilous species are to be found. The most important are those of the Belvédère of the Domaine Solvay (with *Encalypta streptocarpa, Ctenidium* *molluscum*, *Tortella tortuosa*, *Porella platyphylla* and *Campylium chrysophyllum*), those at the ponds of the Ganzepootvijver in Groenendaal (with *Neckera complanata*, *Homalia trichomanoides*, *Encalypta streptocarpa*, *Campylium calcareum*, *Homalothecium lutescens*, *Fissidens dubius* and *Mnium stellare*), and those of the area of the Rouge-Cloître-Trois Fontaines (with *Ctenidium molluscum*, *Campylium chrysophyllum*, *Encalypta streptocarpa* and *Mnium stellare*). These calcareous sandy slopes are very sensitive to erosion. Mostly in very popular areas, they are directly threatened. The very slender *Campylium calcareum* probably disappeared from the Rouge-Cloître due to the disturbance of its habitat. In the Brussels Capital Region, most of these slopes recently became nature reserves and doing this for the north side of the slopes of the ponds in Groenendaal would also be important. Fortunately, some characteristic species of sandy slopes can find a substitution habitat on concrete. This is the case for *Mnium stellare*, *M. marginatum* and *Fissidens dubius*. Some channels of the drainage network, for example those at the intersection of the Drève des deux Triages and the Drève de Lorraine, are a habitat for rare species such as *Rhynchostegiella curviseta*. Species colonizing the drainage network are probably not threatened in the short term. Species colonizing the concrete of walls are much more likely to disappear if the use of pesticides continues. This is unfortunately the case for the railway bridge of the Drève des Bonniers, which is one of the three localities of *Tortula marginata* of the area.

Some ponds of the forest possess a typical bryoflora: *Calliergon cordifolium* in the Petites Flosses, or *Aphanorhegma patens* in the Vuilbeek. Artificial drawdown of these ponds in autumn could allow the recovery of very rare species such as *Physcomitrium eurystomum* and *P. sphaericum*, recorded around the ponds of Hoeilaart at the beginning of the century.

The conservation of old trees and shrubs is also essential for the conservation of bryophytes. In the remnants of alluvial alder-woods and at the edge of the forest, phorophytes such as elder and willow should be especially maintained. They harbour *Platygyrium repens*, *Orthotrichum obtusifolium*, *O. pulchellum* near the ponds of the Enfants Noyés, *O. tenellum* in the valley of the Vuilbeek, *Pterigynandrum filiforme* and *Leskea polycarpa* at the ponds of Hoeilaart. Though no particular rarities are found in the oldest oakwoods, such as those in the Bois des Capucins, they have interesting assemblages of *Plagiothecium laetum* and *Herzogiella seligeri*. The spruce wood above the Petites Flosses is the only locality in the Forest of Soignes of *Sphagnum palustre* and *S. subnitens*, accompanied by other interesting species such as *Calypogeia neesiana*. These species would suffer from the use of heavy machines and from clear felling.

Clear felling of trees is, in other respects, very detrimental to the bryoflora. *Frullania fragilifolia* was recorded by Vanden Berghen (1941) at the Fonds des Ails in La

Hulpe, and *Lejeunea ulicina* was very abundant there (De Zuttere 1981). They disappeared here after clear felling of the old hornbeams. In most parts of the forest a very simple forest structure is maintained with a single layer of selected beech with straight boles more than 30 m high. Because of this management diversity of phorophytes is low, very old and sinuose trees are rare and the forest mesoclimate is less humid. As a consequence the epiphytism is often very poor and restricted to the foot of the trees. It consists of non exclusive epiphytes such as *Mnium hornum* (De Zuttere & Sotiaux 1992), xerophilous species such as *Dicranoweisia cirrata* or spreading species such as *Dicranum tauricum*. This management probably also caused the disappearance of species such as *Antitrichia curtipendula* and *Neckera pumila*, which testified the very old age of the forests and its complex structure with glades as well as densely covered spots. Certain areas in the forest should therefore be designated as old growth reserves.

4.4 Conclusion

The number of bryophytes, the bryological diversity, of the Forest of Soignes did not decrease since the former inventories. However, although certain forest species of great phytogeographical interest were found new for the area, the diversity is now largely due to the spread of non forest species in ruderal and man-made habitats. Genuine and rare forest species disappeared. Currently, a third of the species occur in one or few localities and are very likely to follow the same fate. Most of the bryologically interesting sites cover small and well-known areas. A few conservation measures and specific management measures included in the management plan of the forest would allow their survival.

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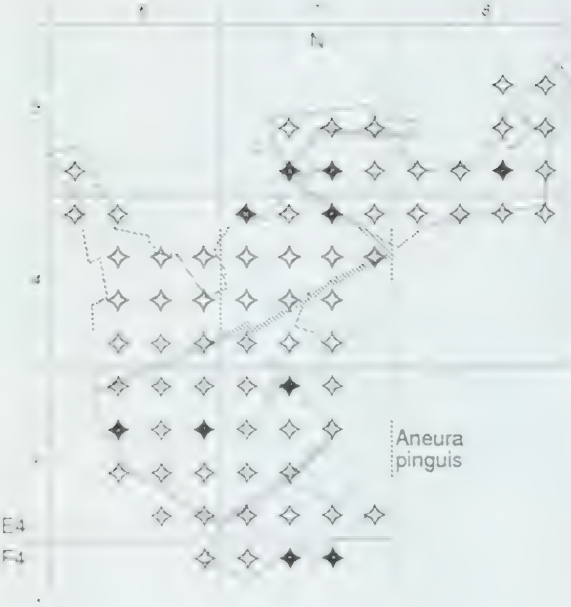
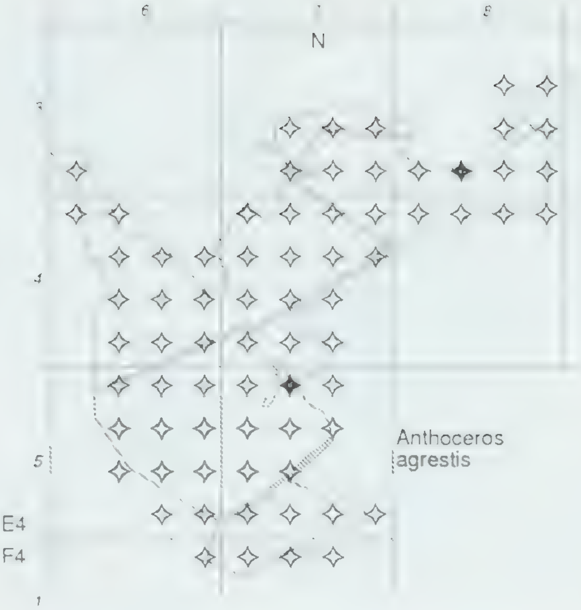
Distribution maps

Liverworts
(*Aneura - Sphaerocarpus*)
followed by
mosses
(*Aloina - Zygodon*)



Aneura pinguis



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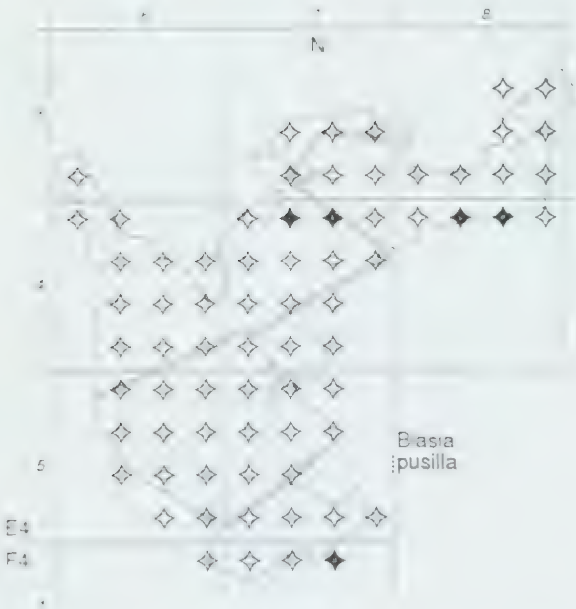

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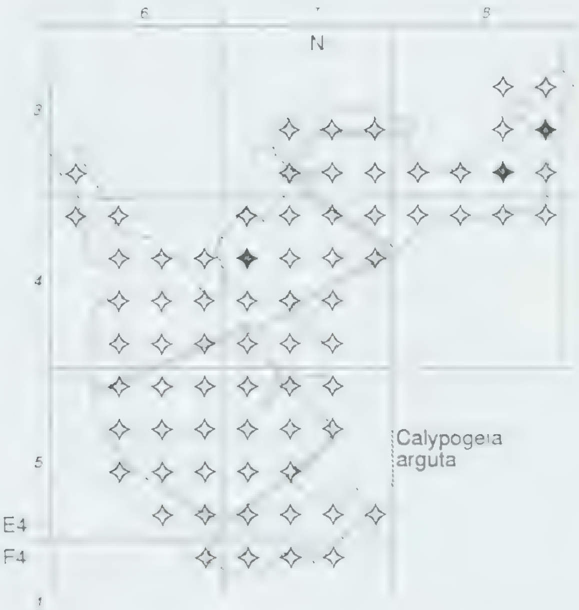

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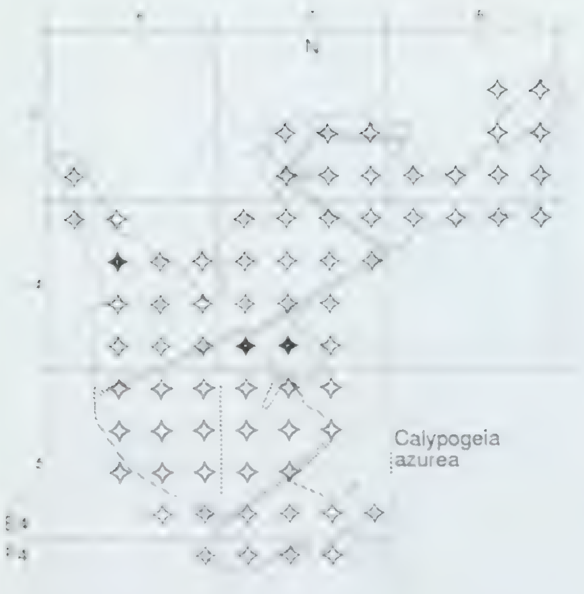

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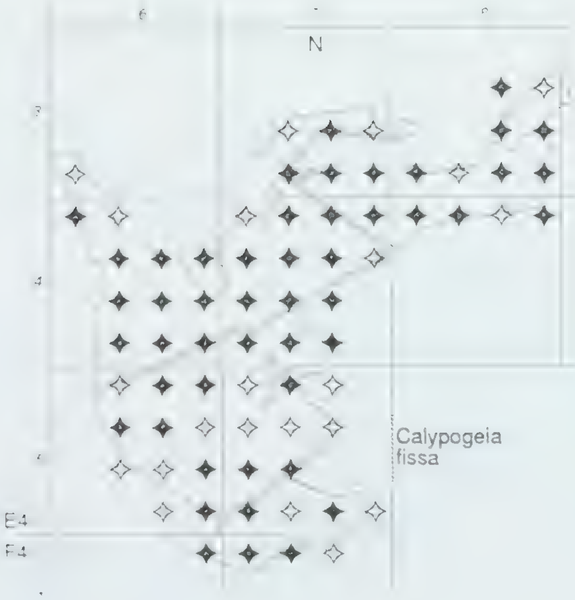

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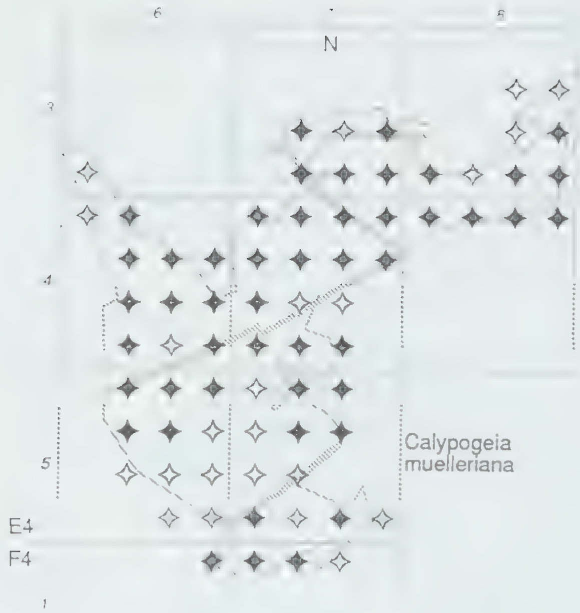

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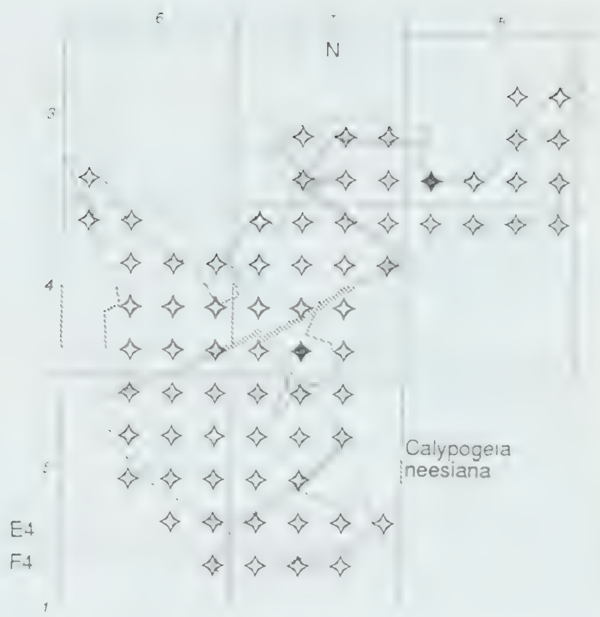

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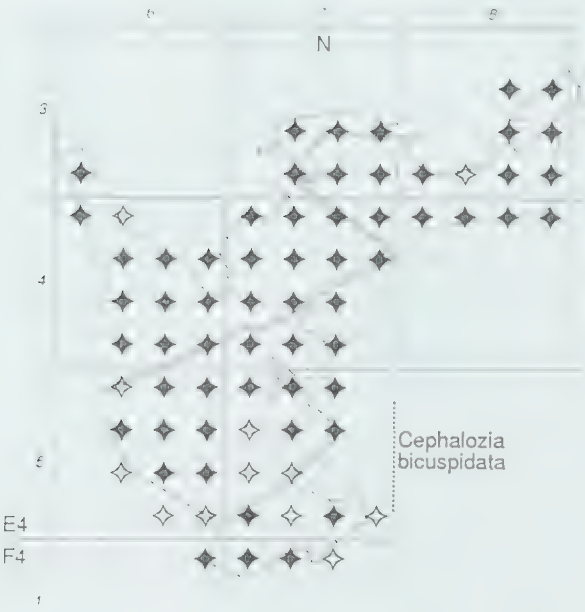

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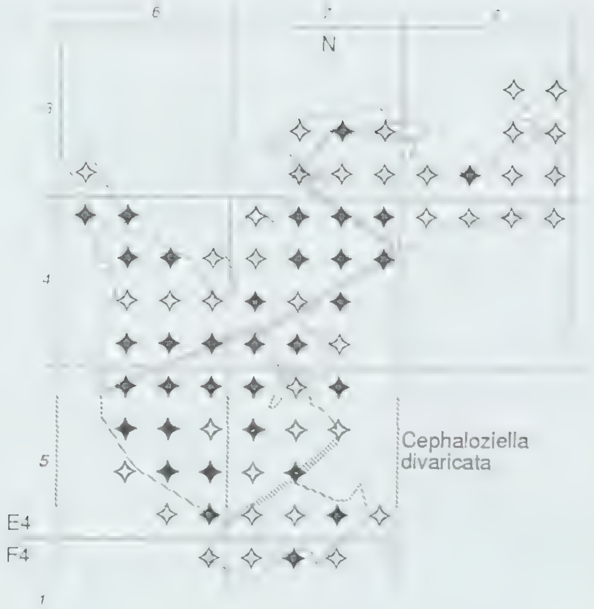
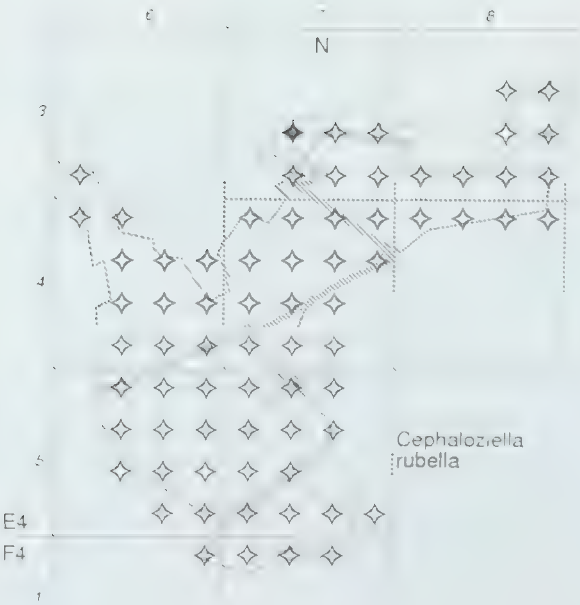
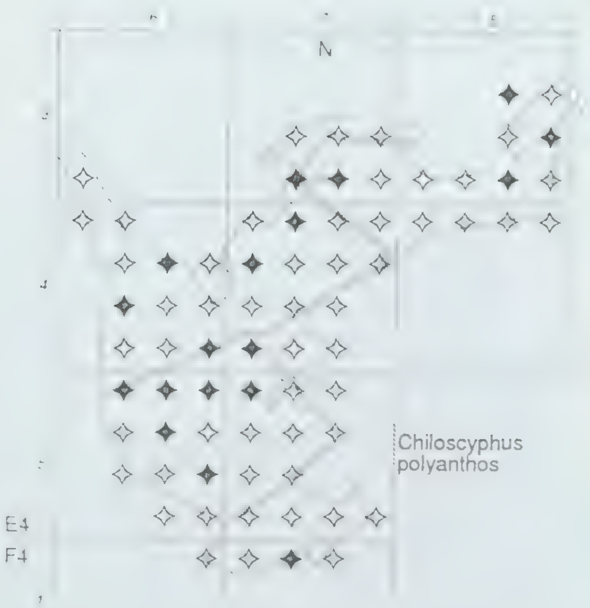


Cephaloziella divaricata



Cephaloziella rubella



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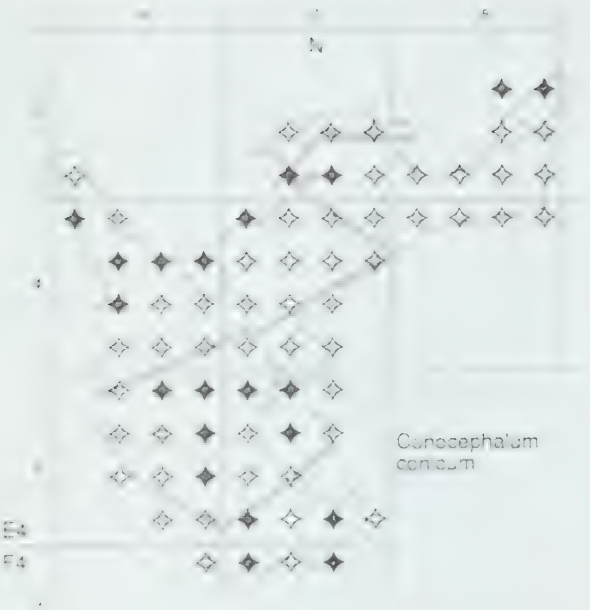
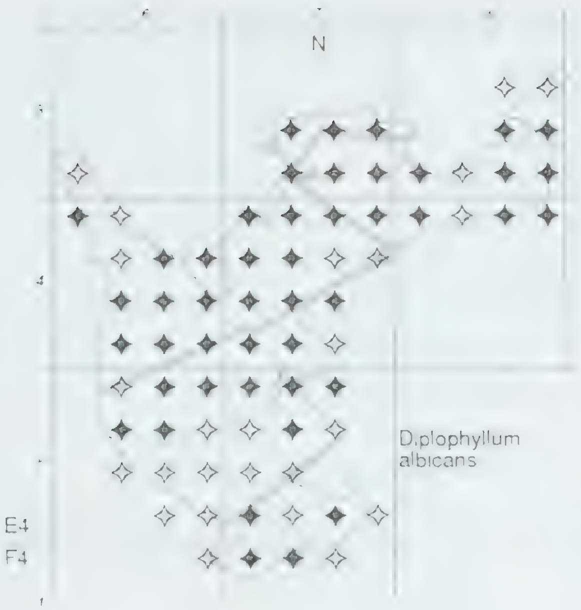
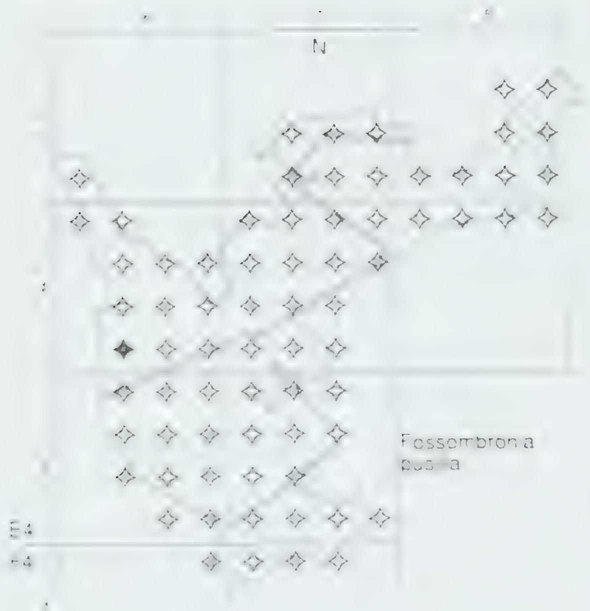


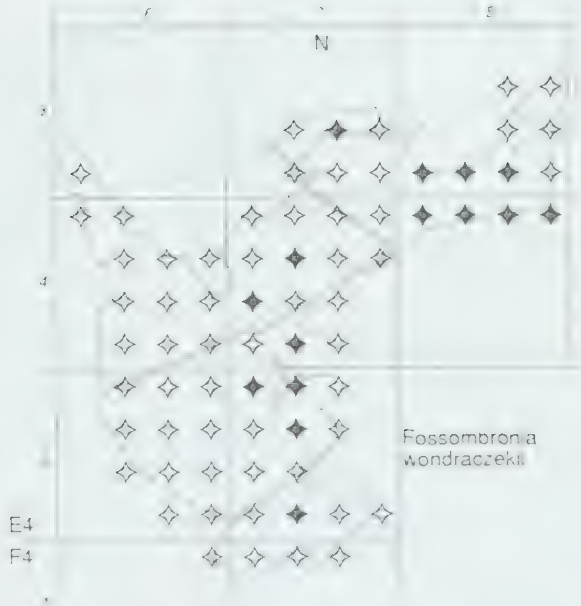
Conocephalum conicum



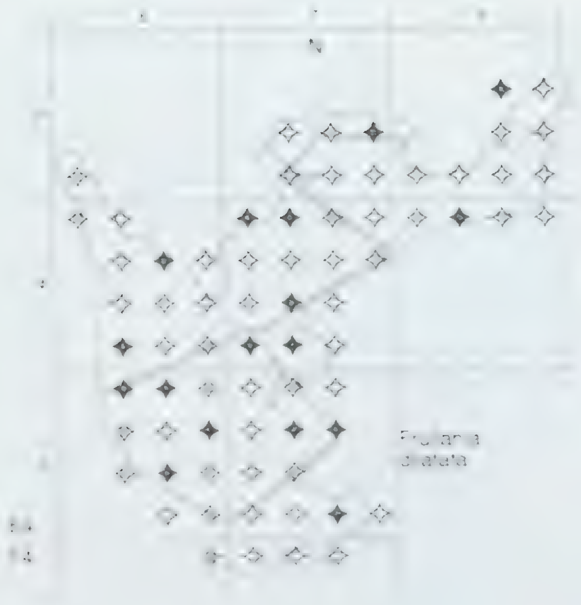
Diplophyllum albicans



Fossombronia pusilla



Fossombronia wondraczekii



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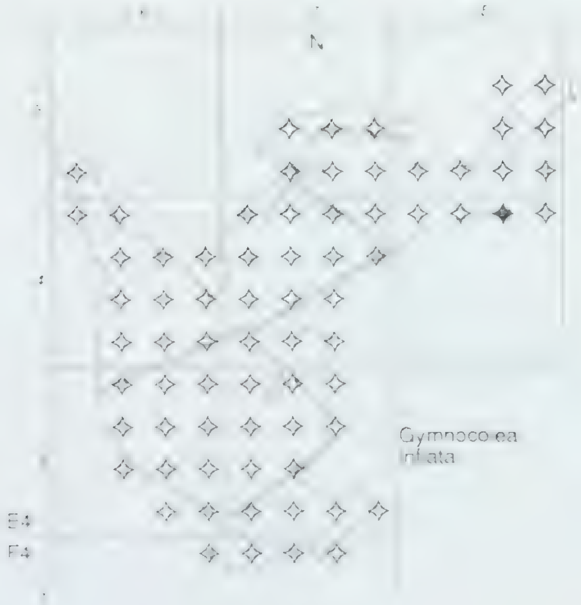

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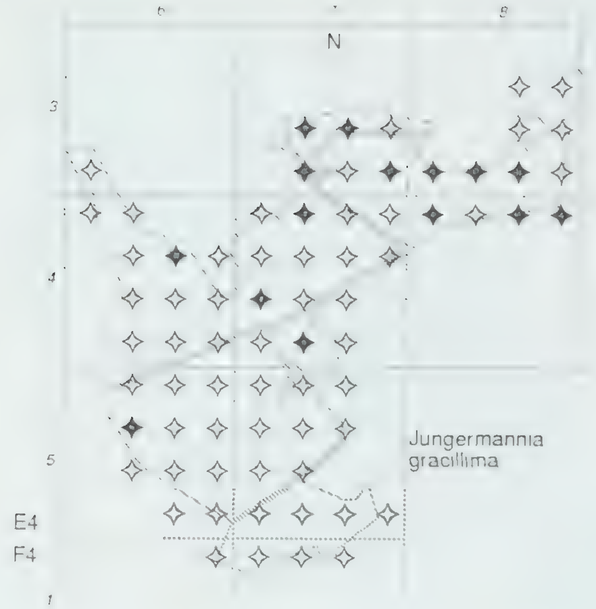

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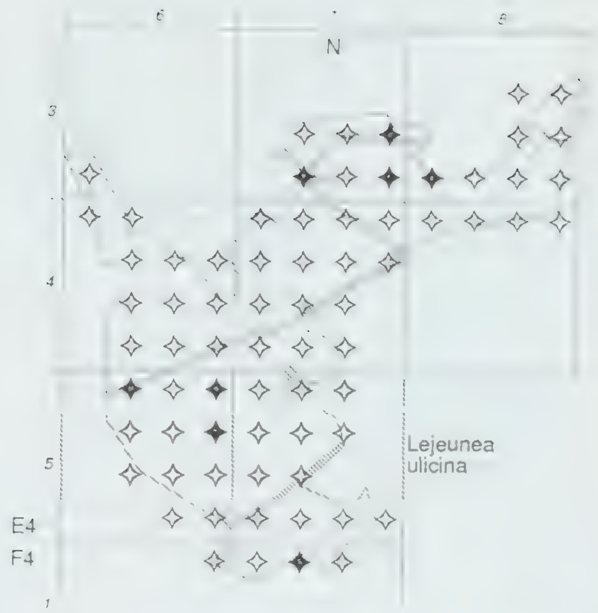

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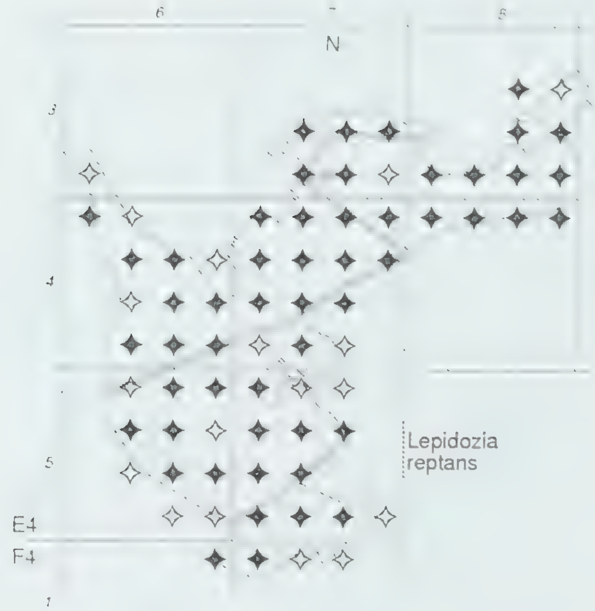

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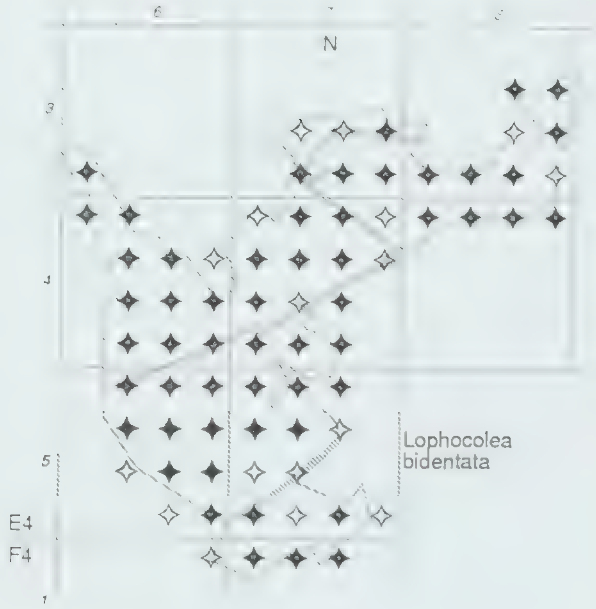

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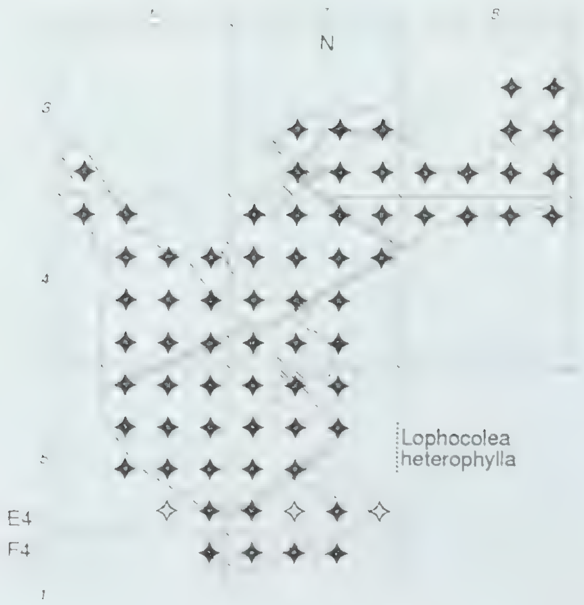

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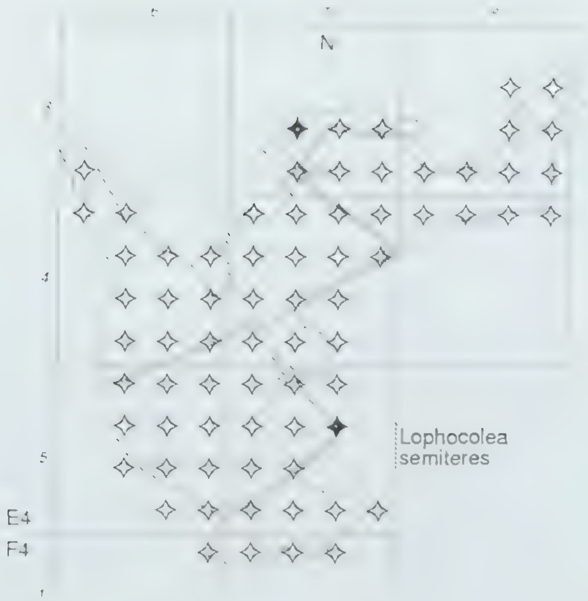

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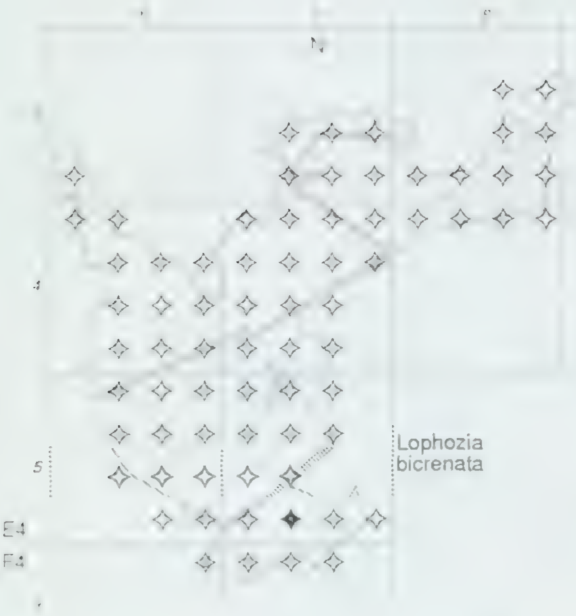

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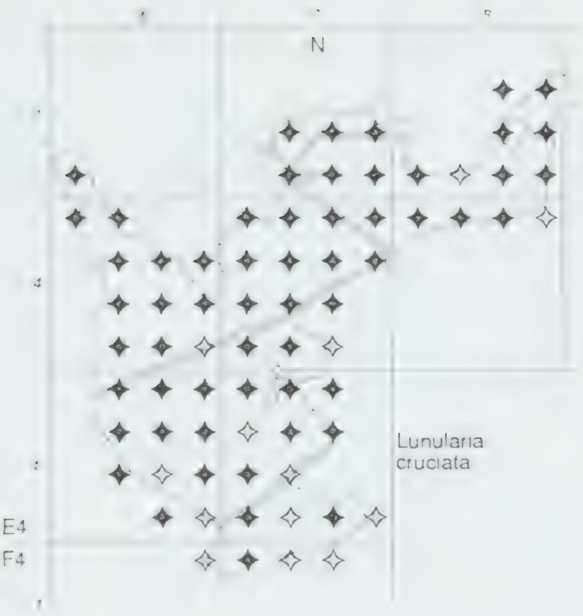

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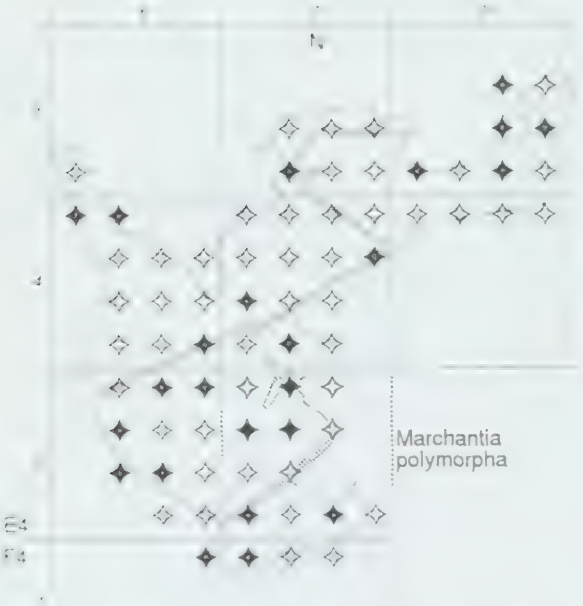

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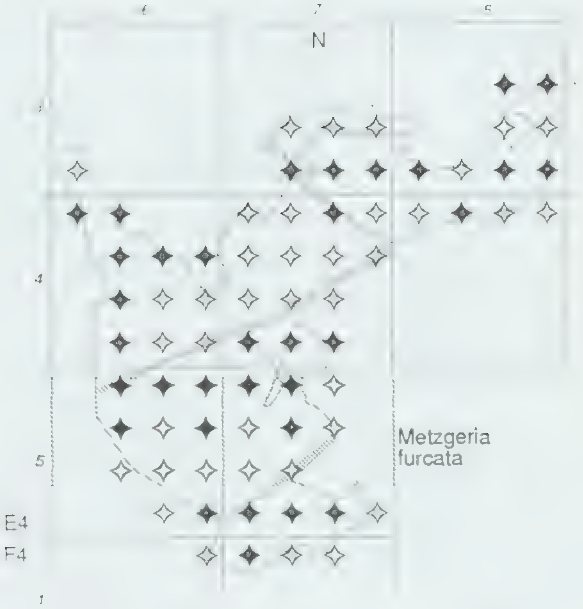

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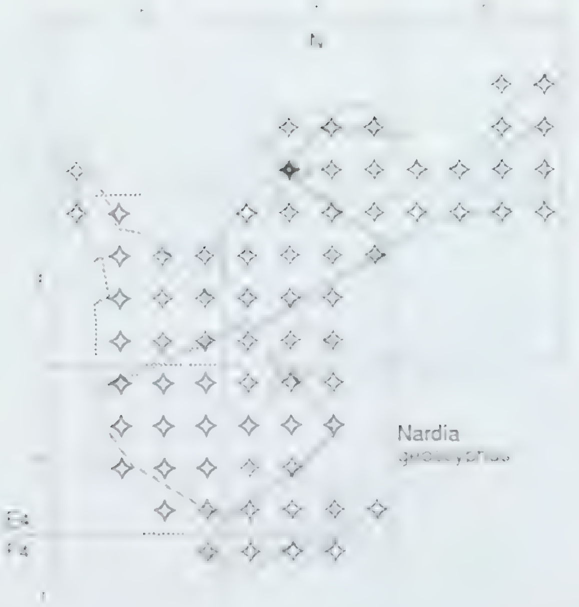

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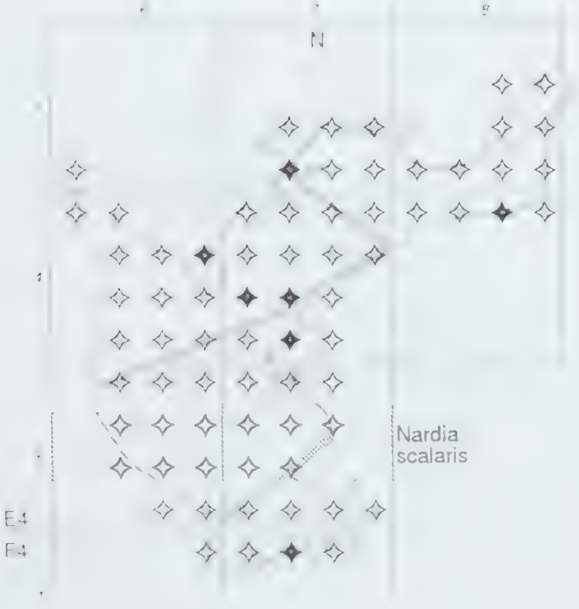

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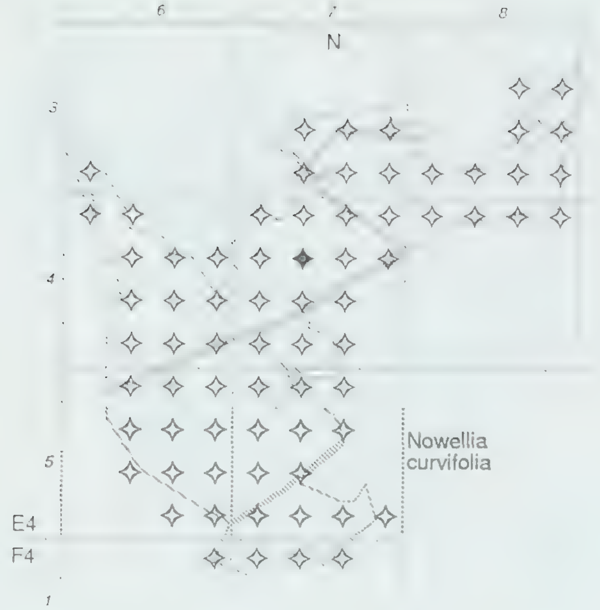
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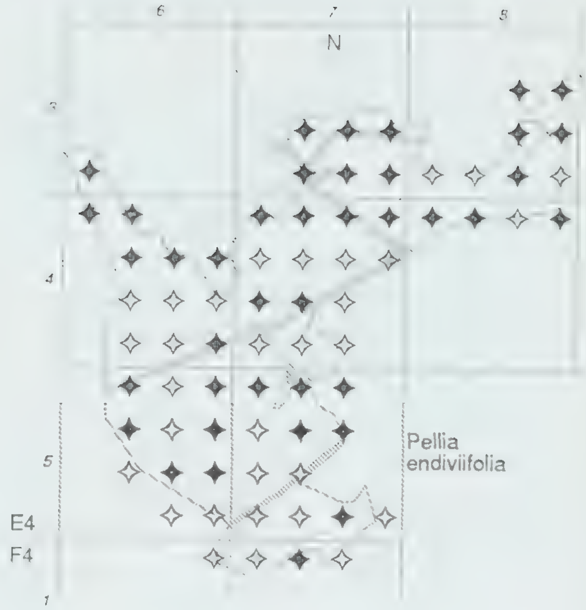
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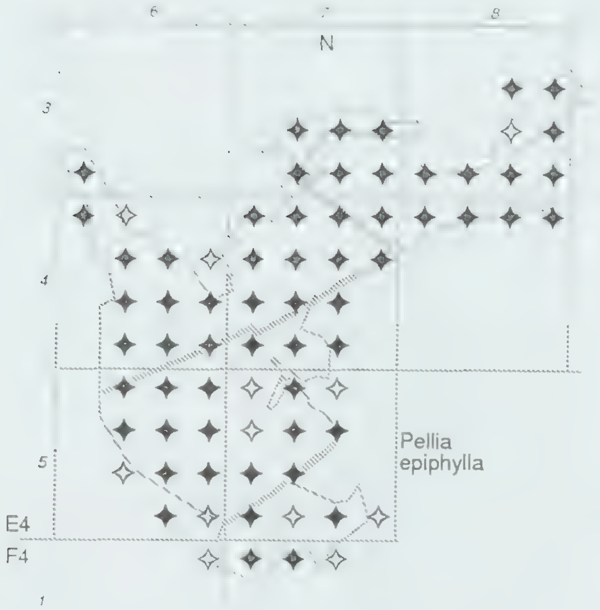
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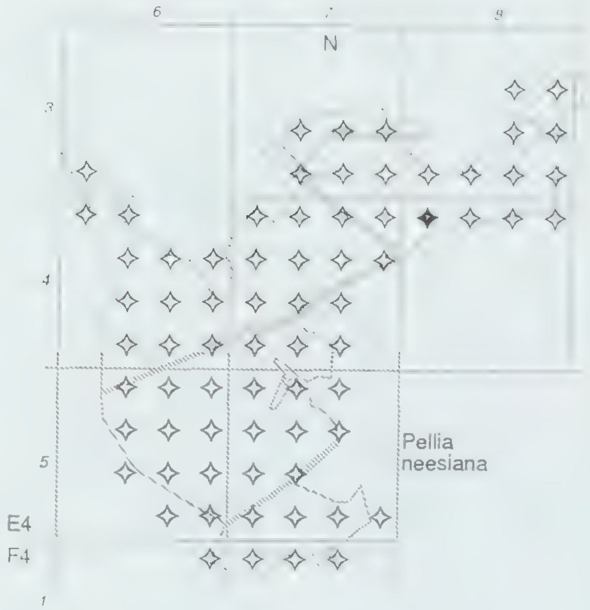
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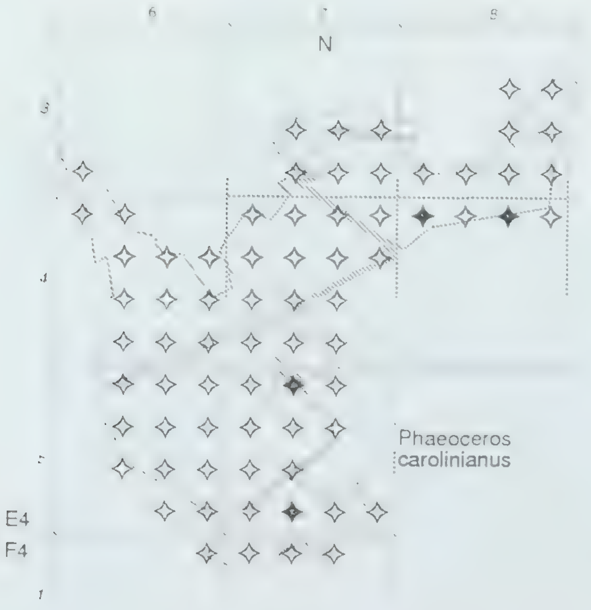
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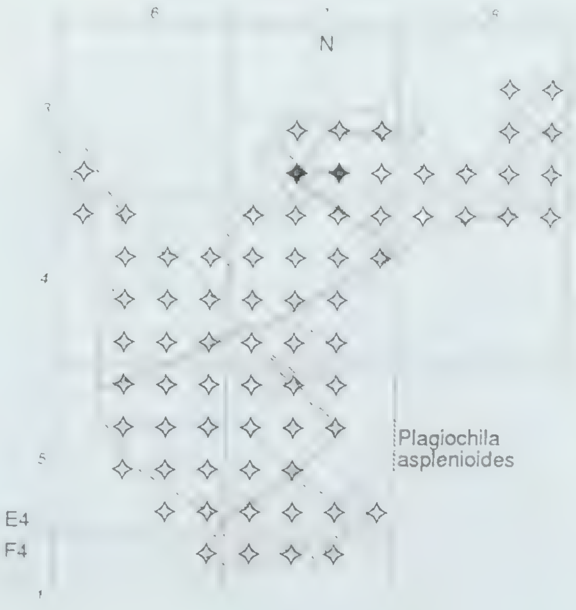
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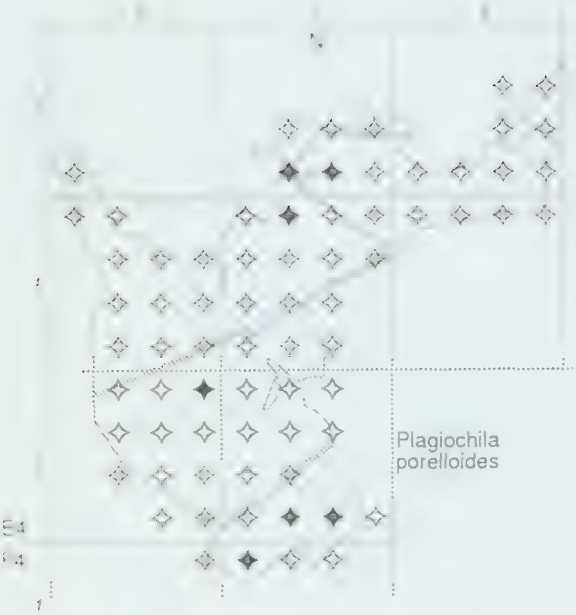

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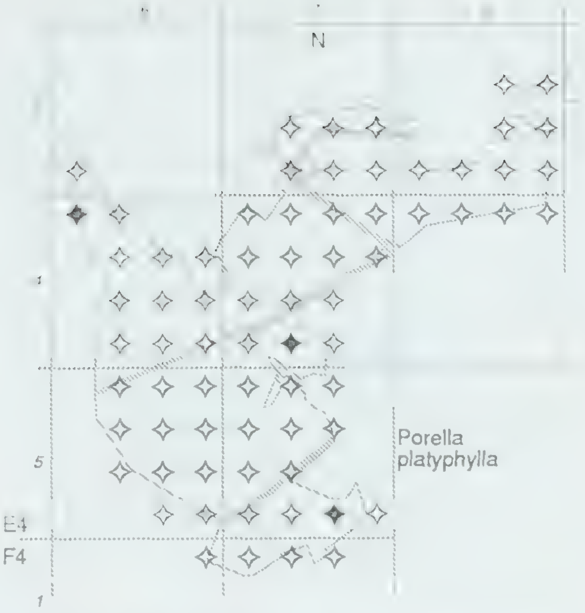

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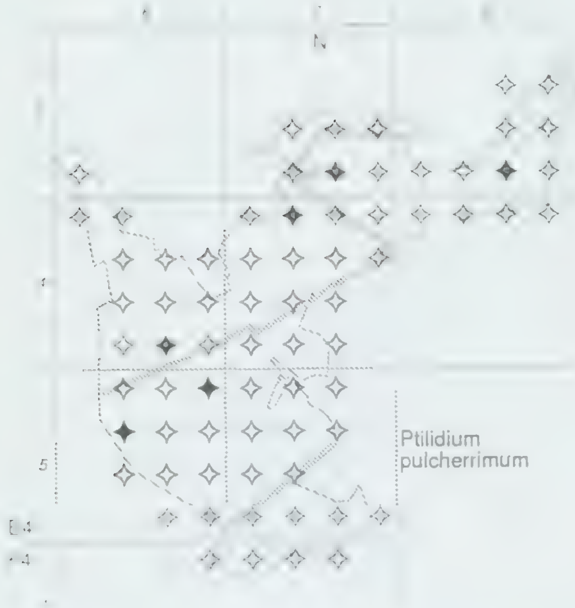

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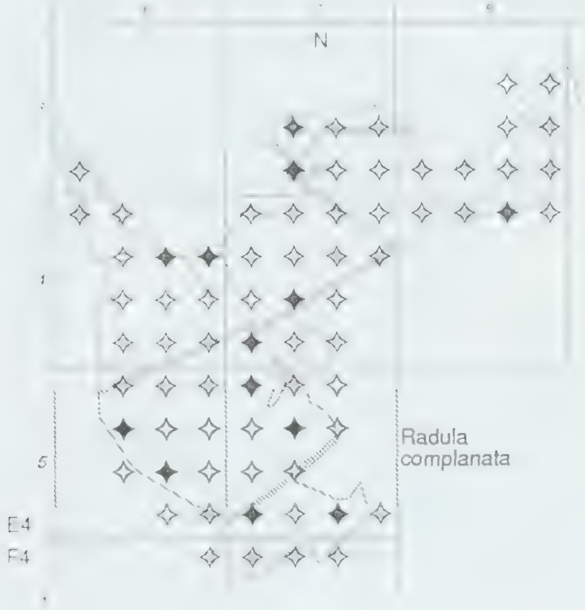
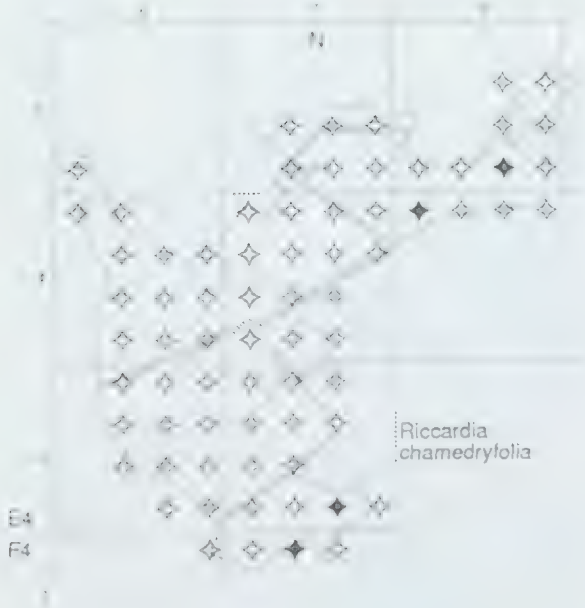


Radula complanata



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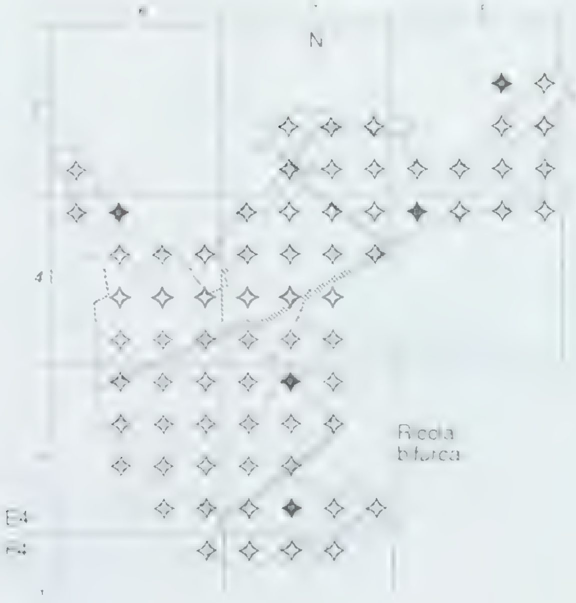

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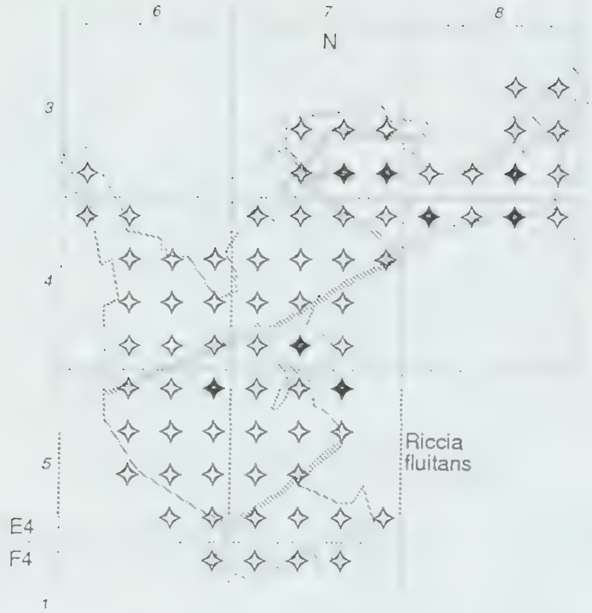

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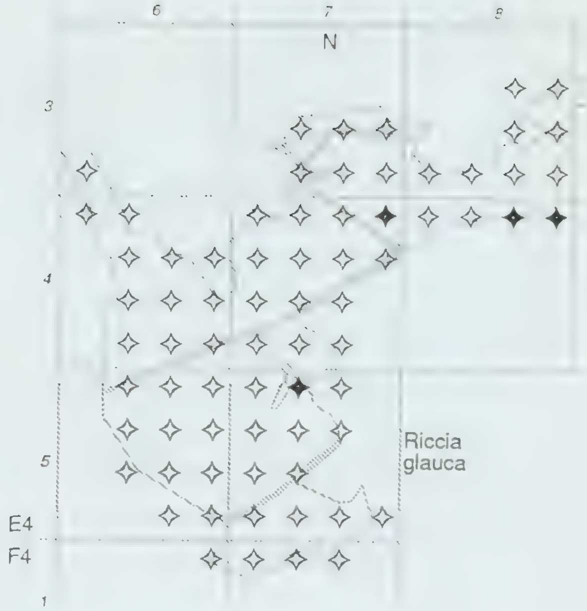

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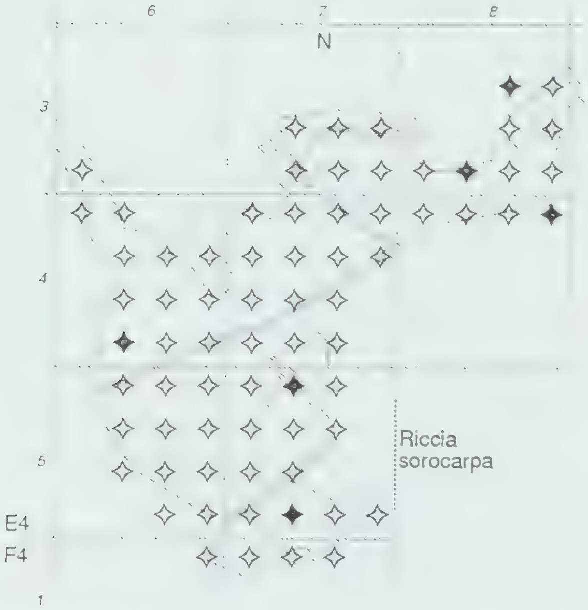

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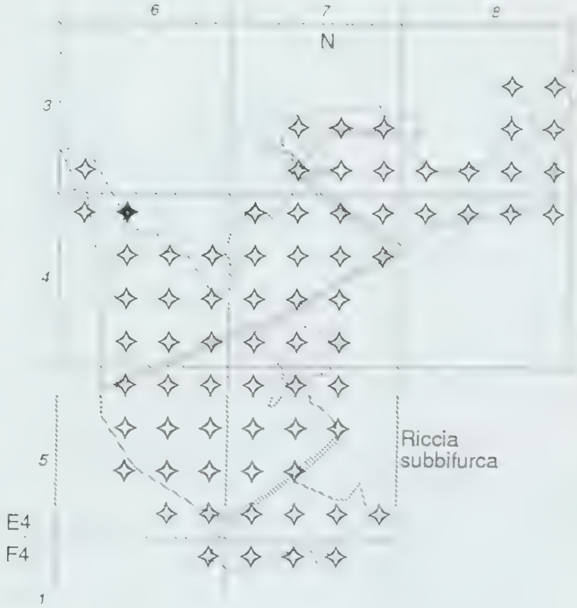
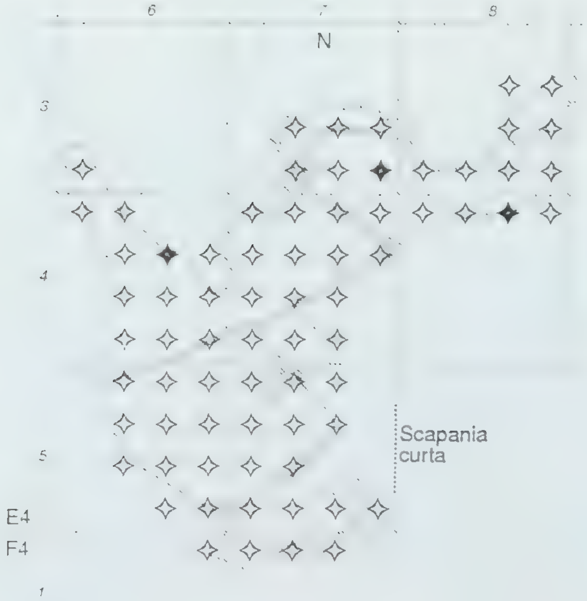
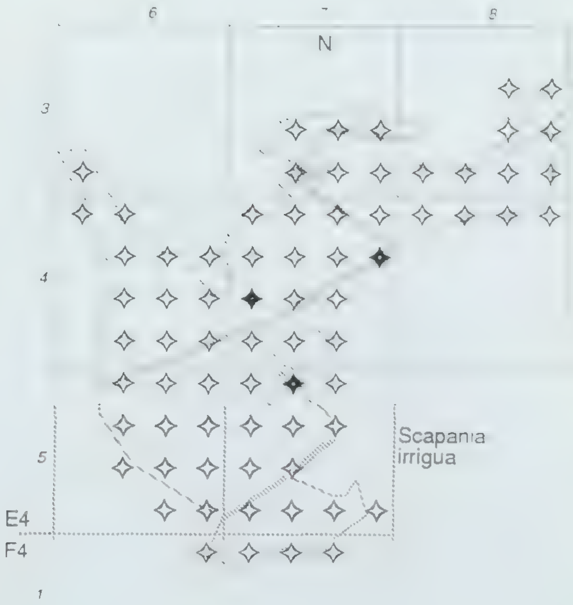


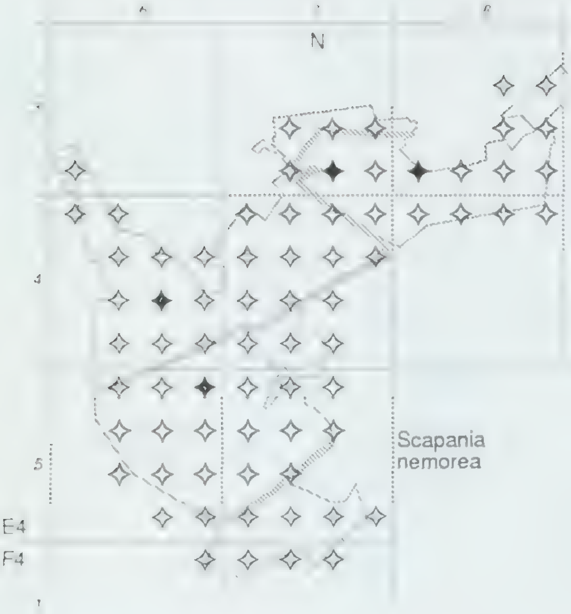
Riccia subbifurca



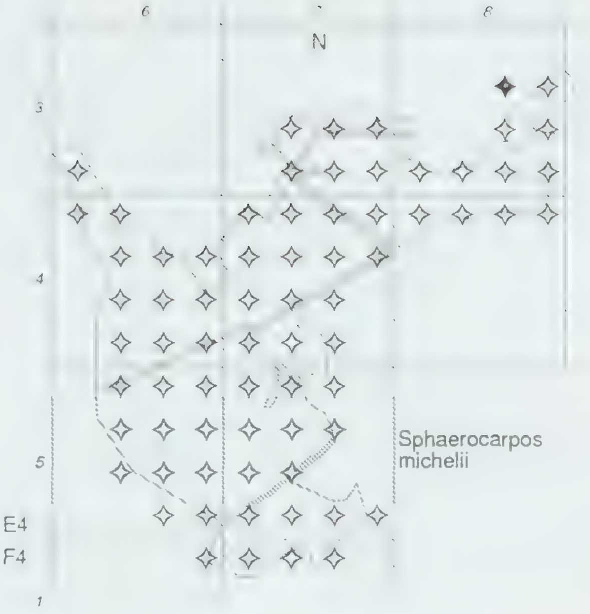
Scapania curta



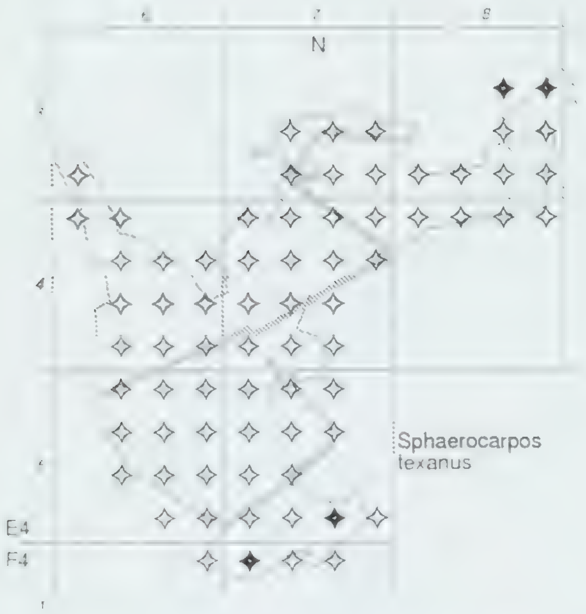
Scapania irrigua



Scapania nemorea



Sphaerocarpos michelii



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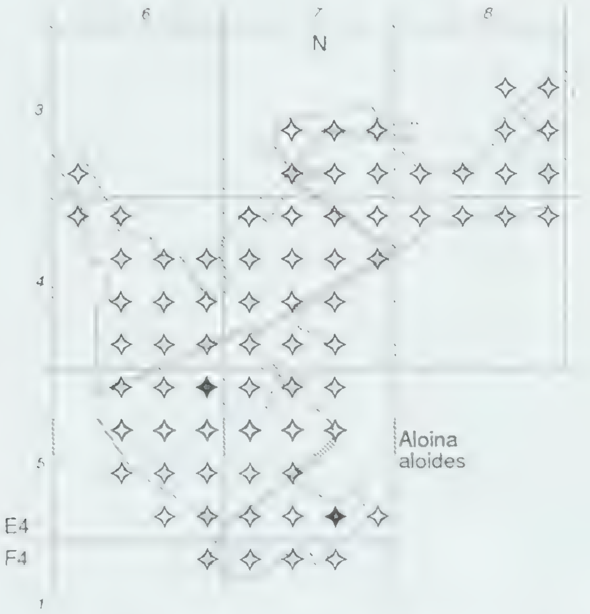
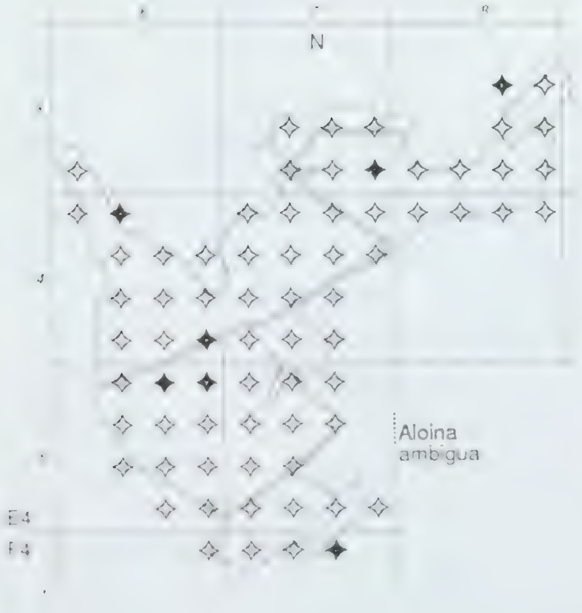
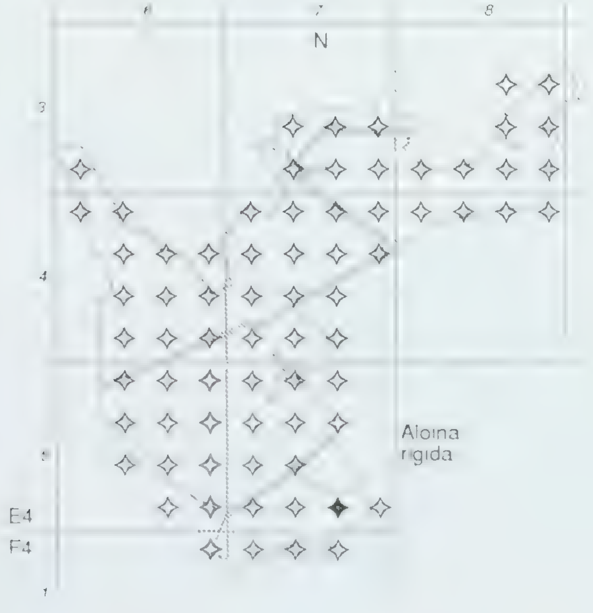


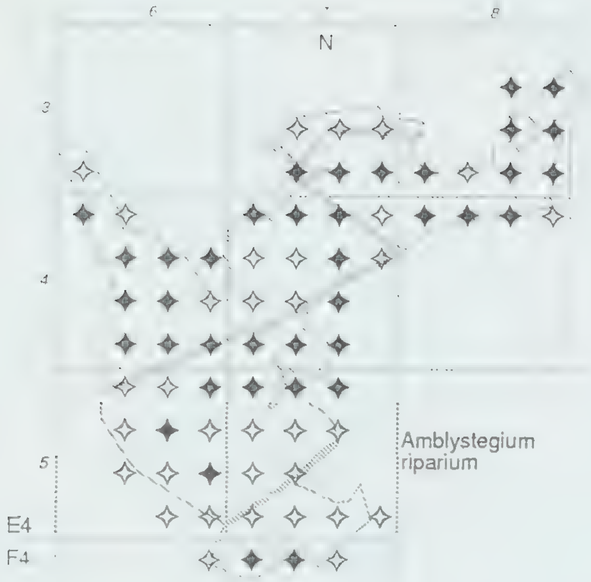
Aloina aloides



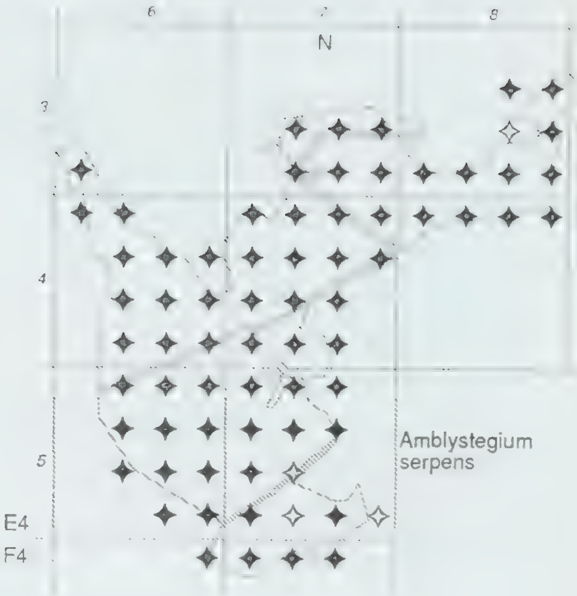
Aloina ambigua



Aloina rigida



Amblystegium riparium



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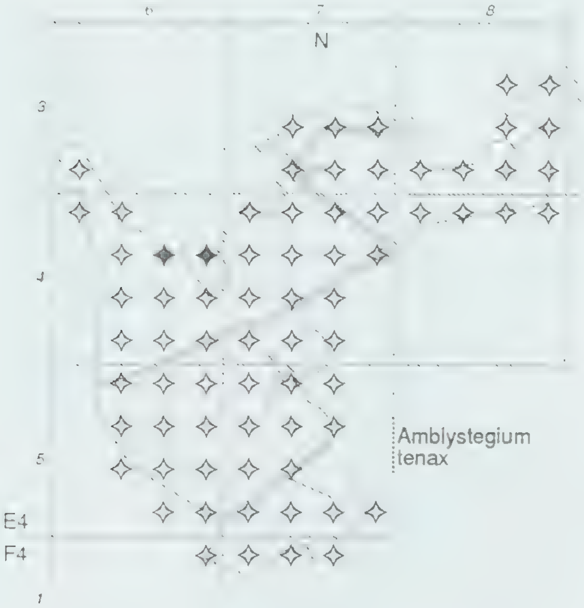

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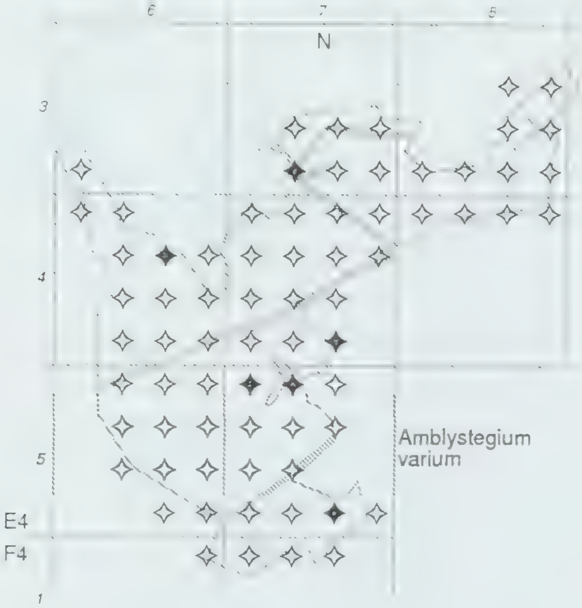

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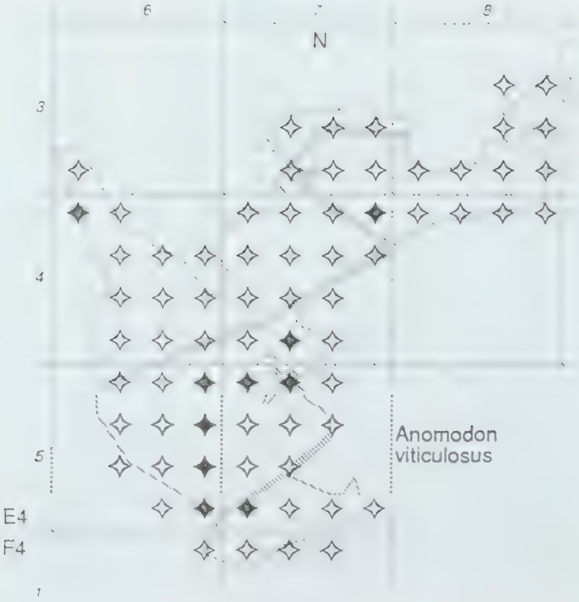
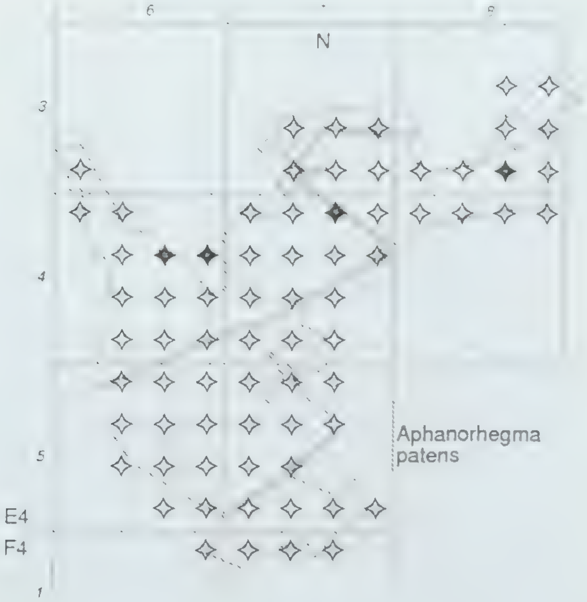
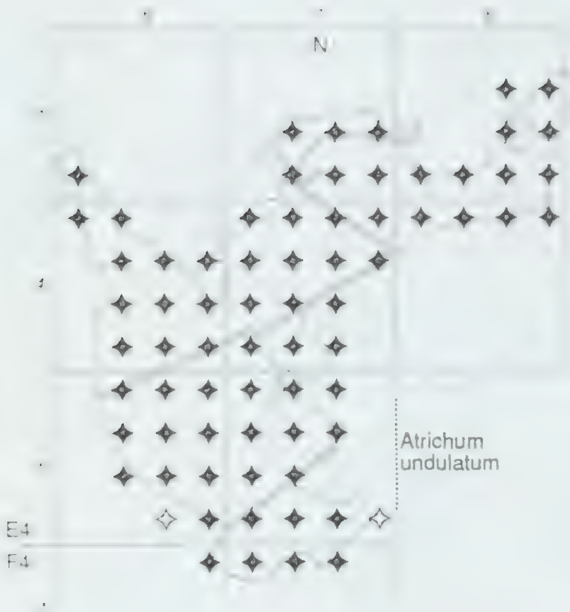
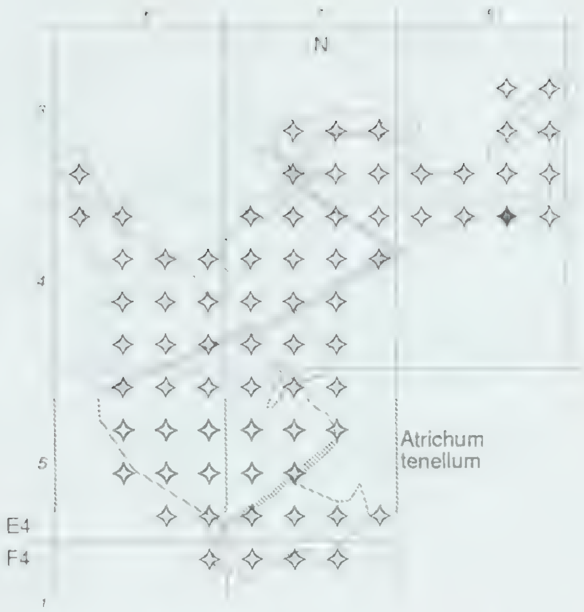


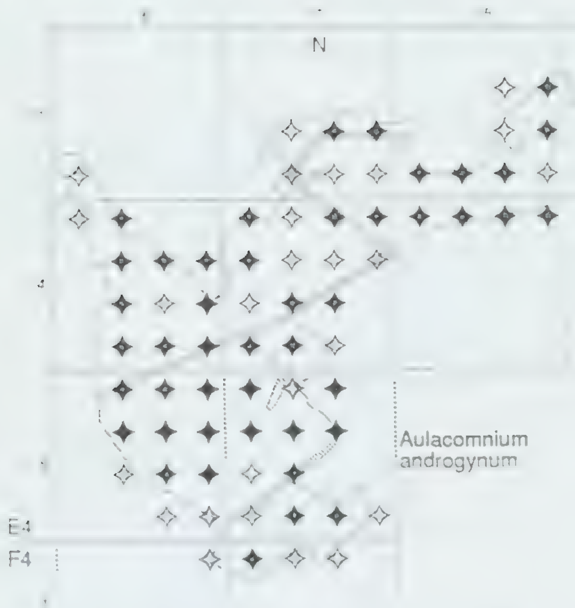
Anomodon viticulosus

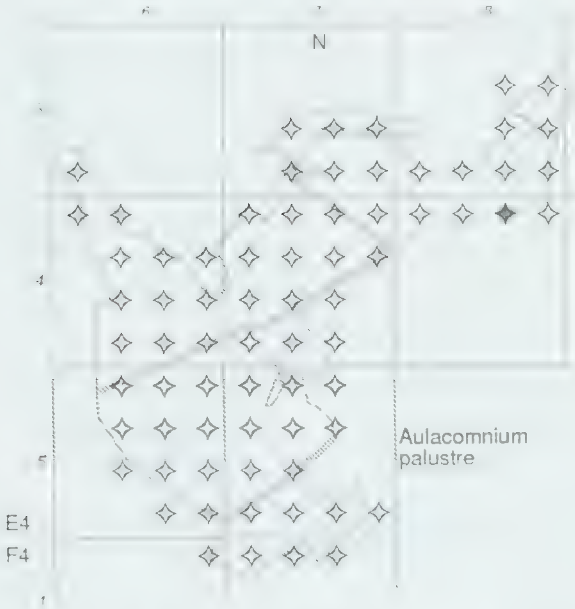


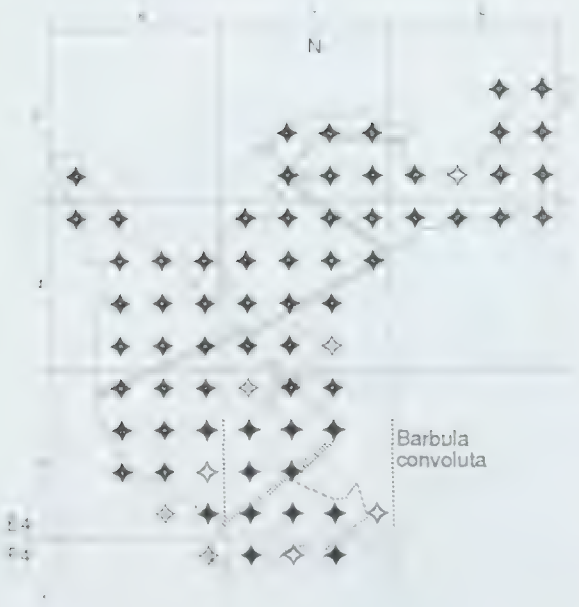
Aphanorhegma patens

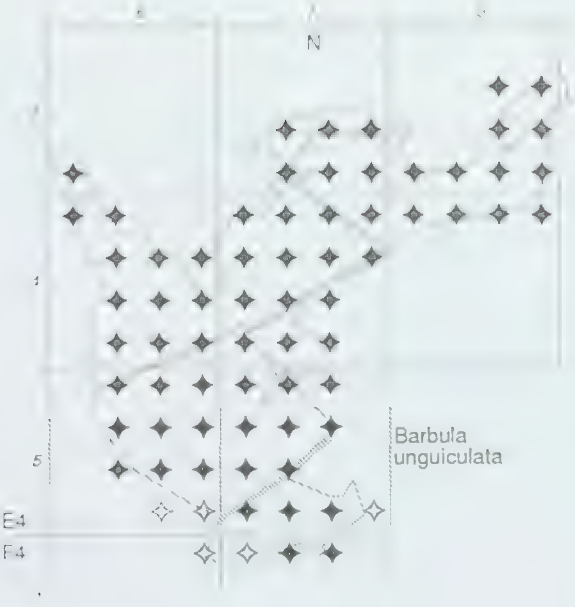

N
Atrichum
undulatum
E4
F4

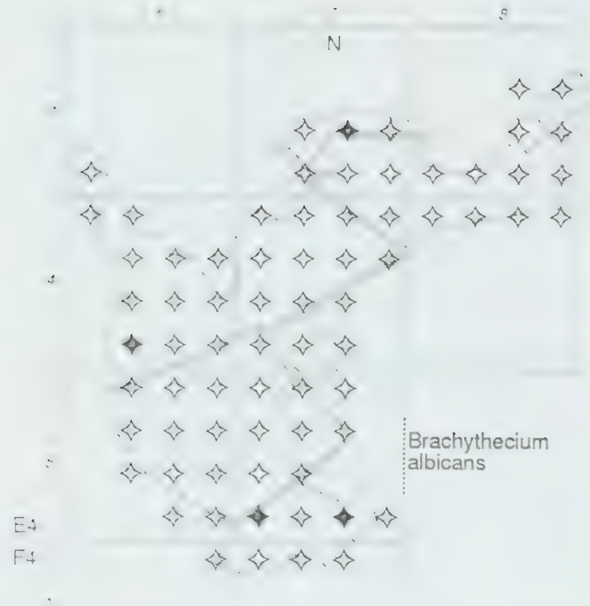

N
4
5
Atrichum
tenellum
E4
F4


N
Aulacomnium
androgynum
E4
F4

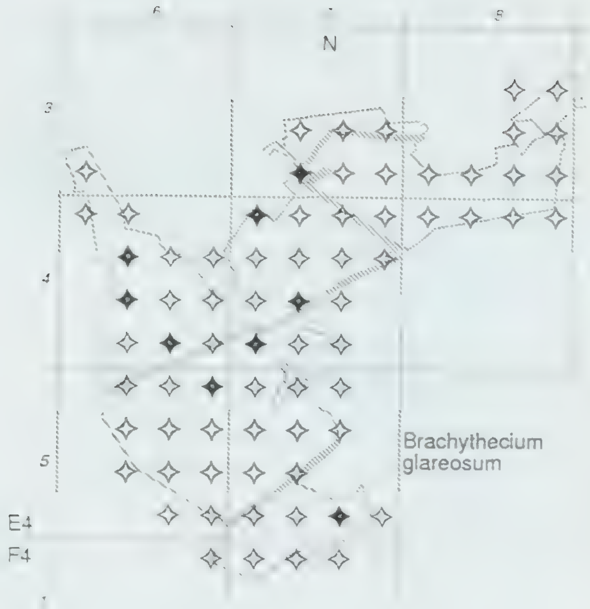

N
4
5
Aulacomnium
palustre
E4
F4


N
Barbula
convoluta
E4
F4

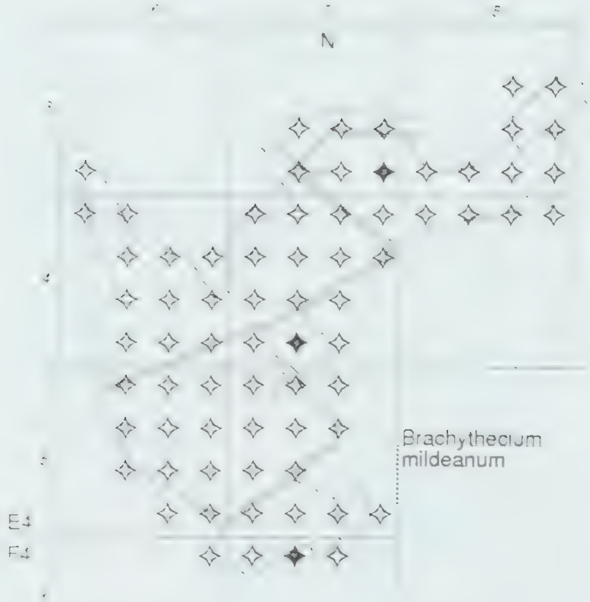

N
5
Barbula
unguiculata
E4
F4



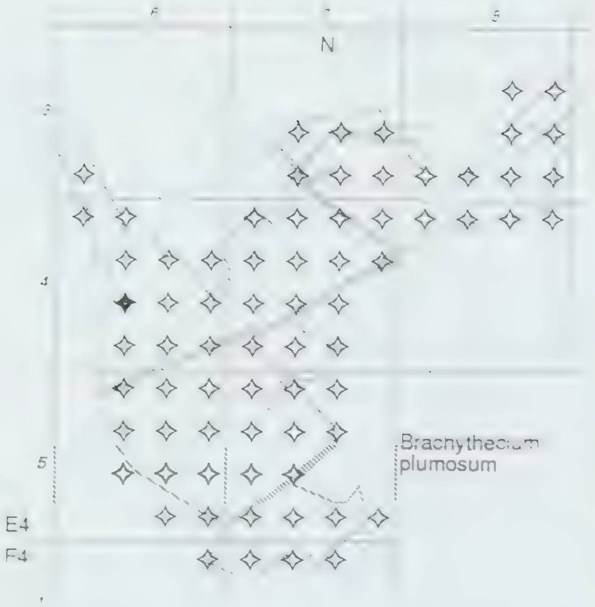
Brachythecium albicans



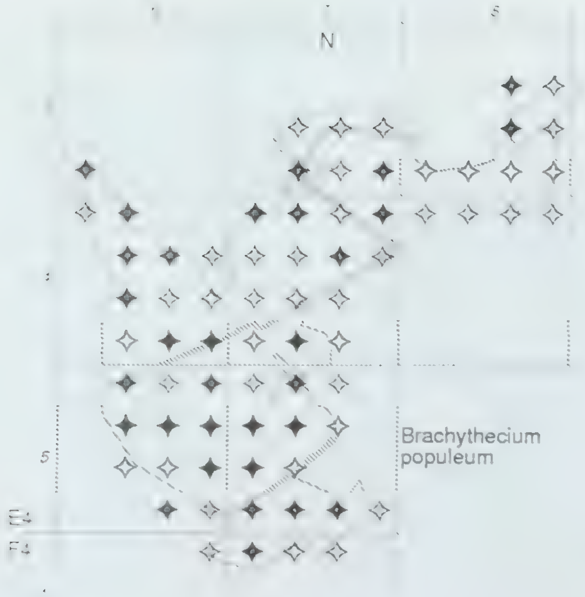
Brachythecium glareosum



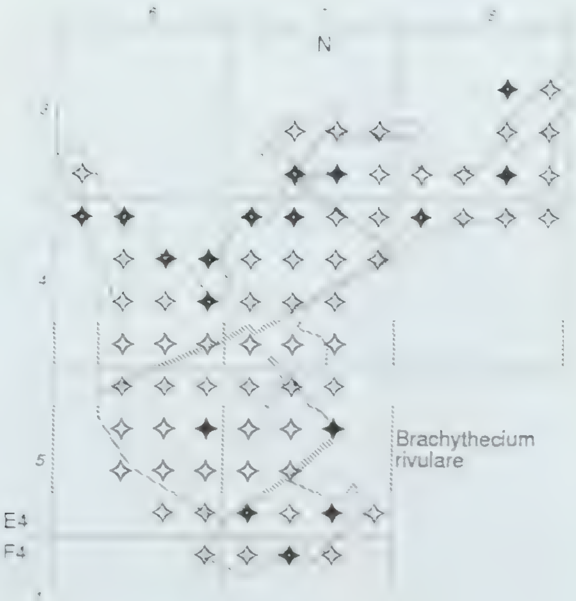
Brachythecium mildeanum



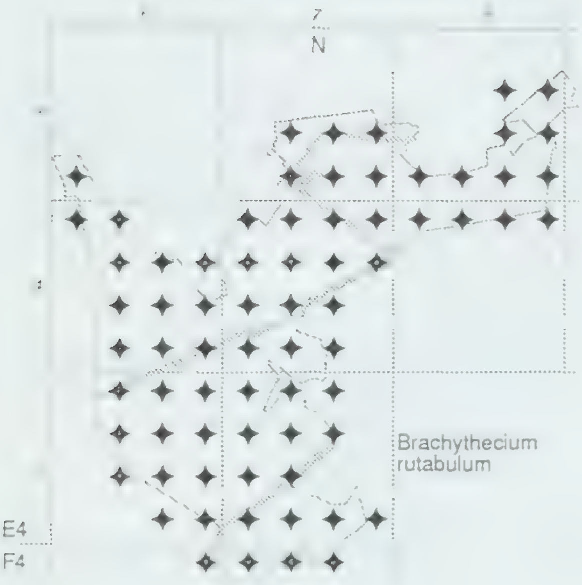
Brachythecium plumosum



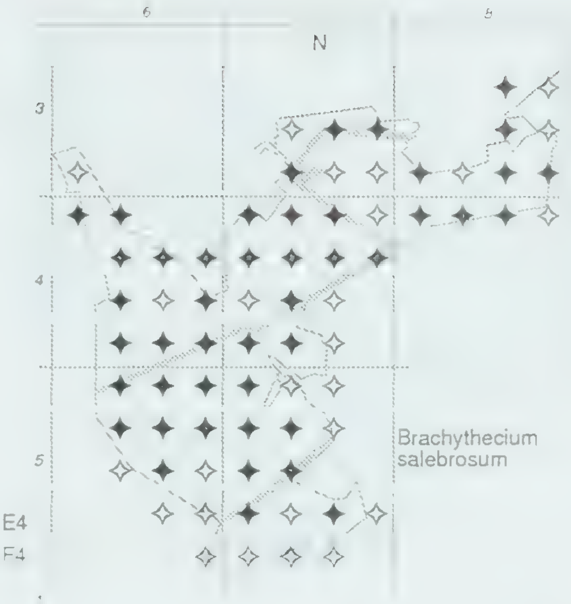
Brachythecium populeum



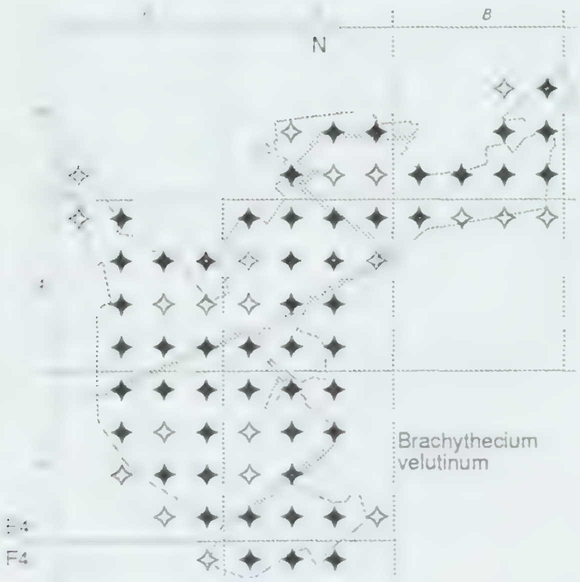
Brachythecium rivulare



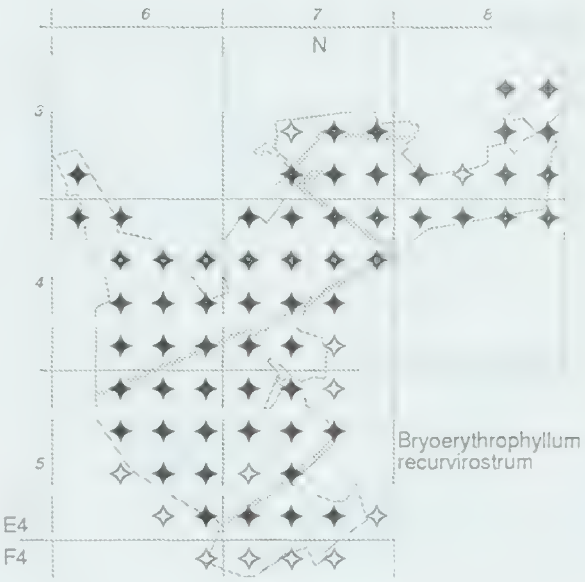
Brachythecium rutabulum



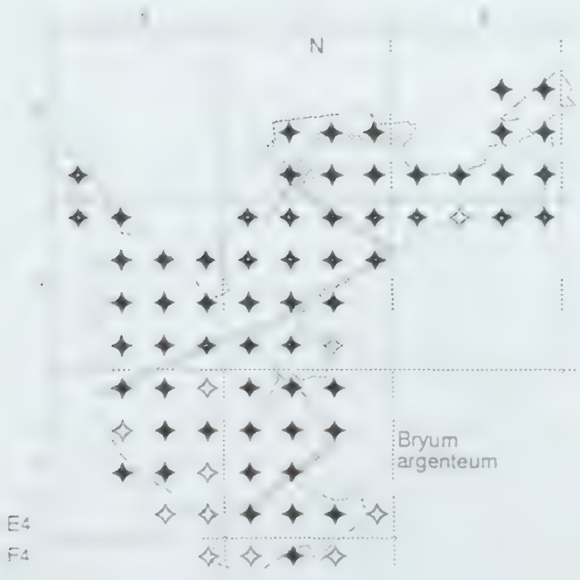
Brachythecium salebrosum



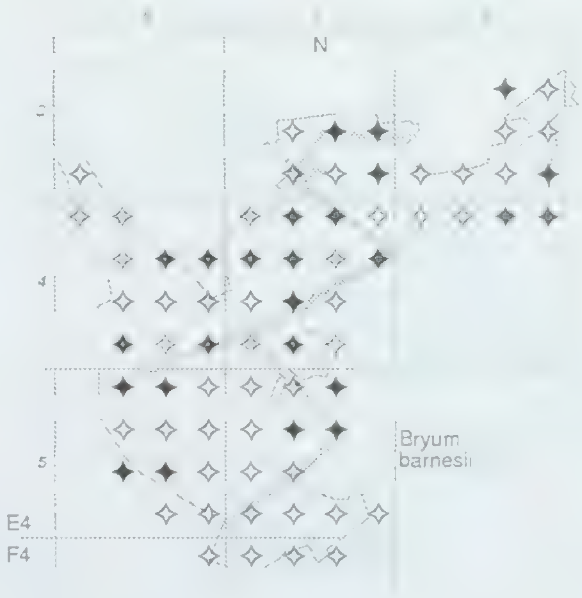
Brachythecium velutinum



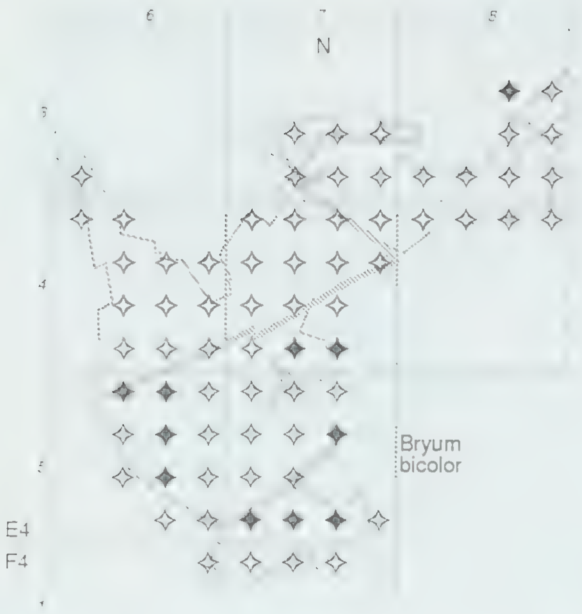
Bryoerythrophyllum recurvirostrum



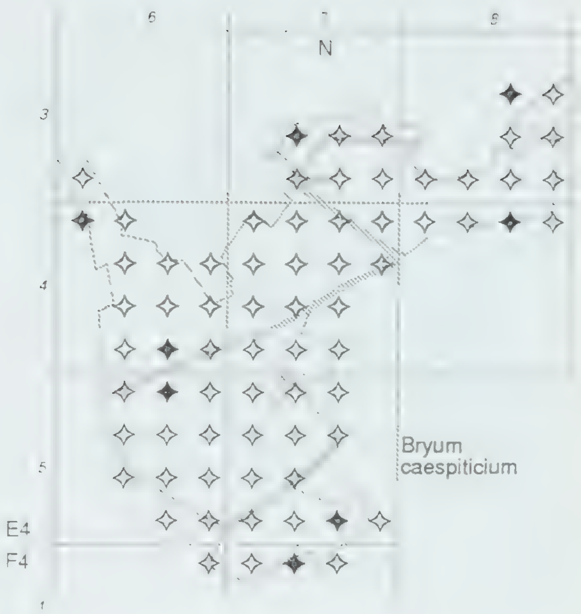
Bryum argenteum



Bryum barnesii



Bryum bicolor



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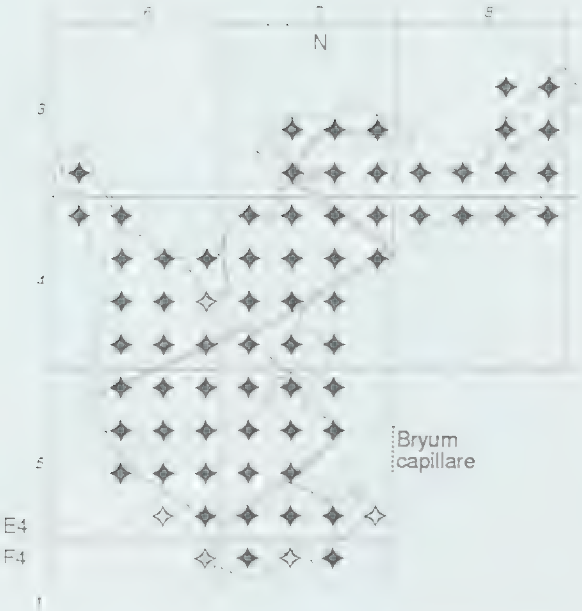

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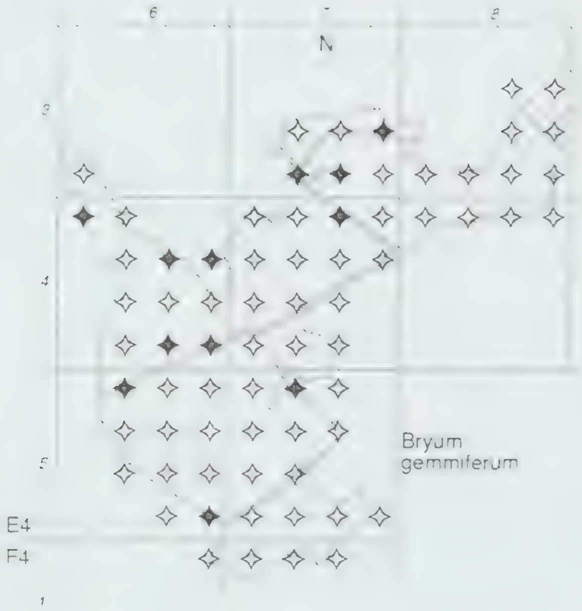

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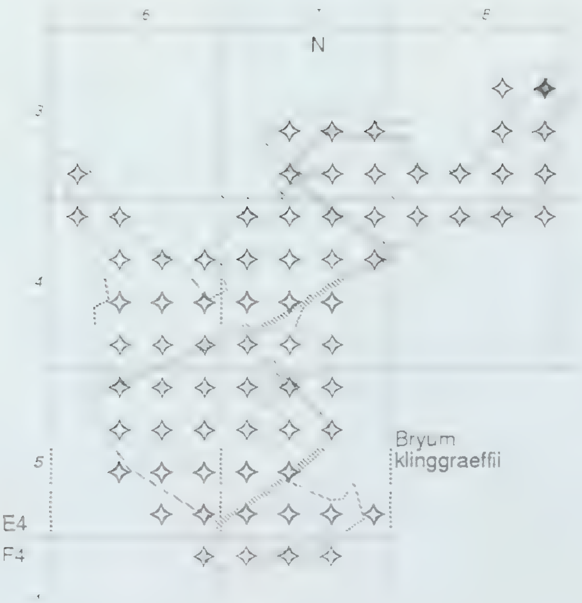
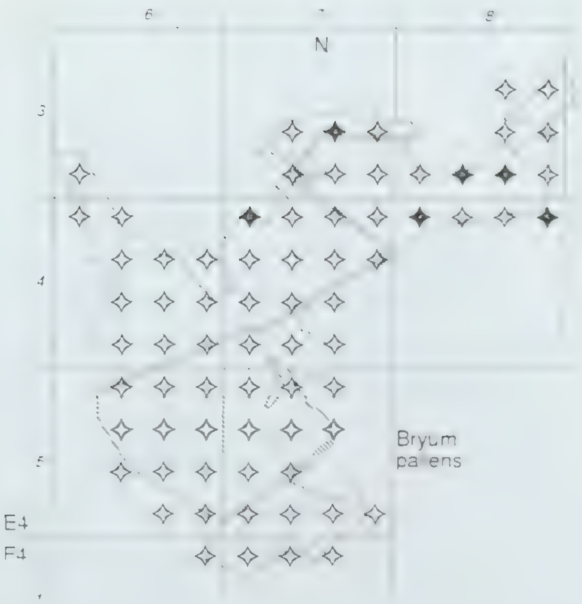
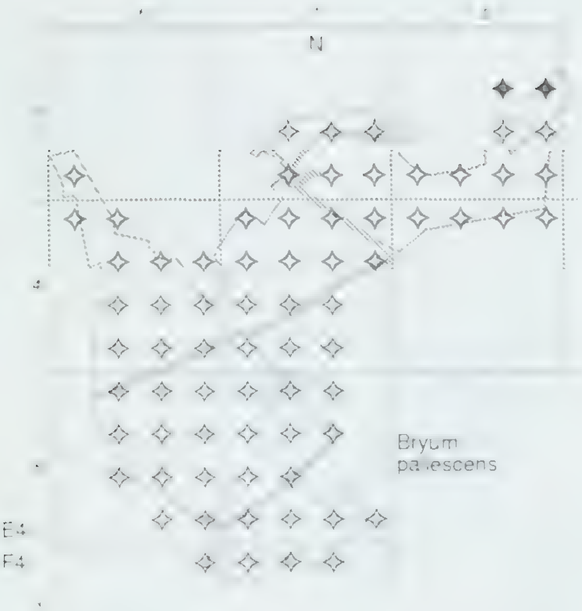
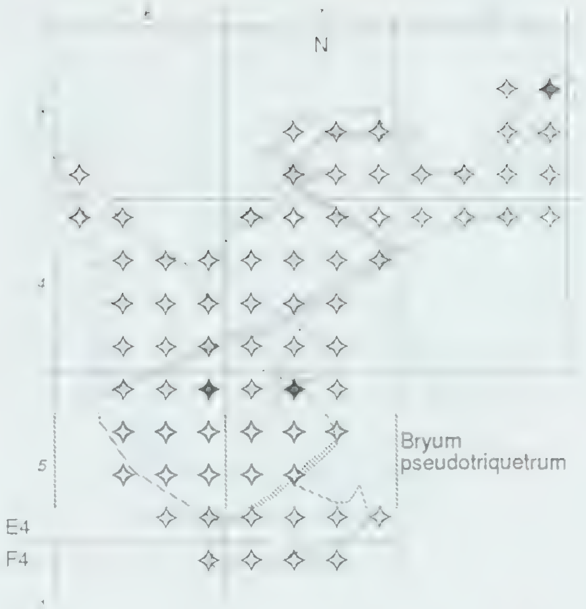


Bryum klinggraeffii



Bryum pallens


N
4
E4
F4
Bryum pallescens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F4
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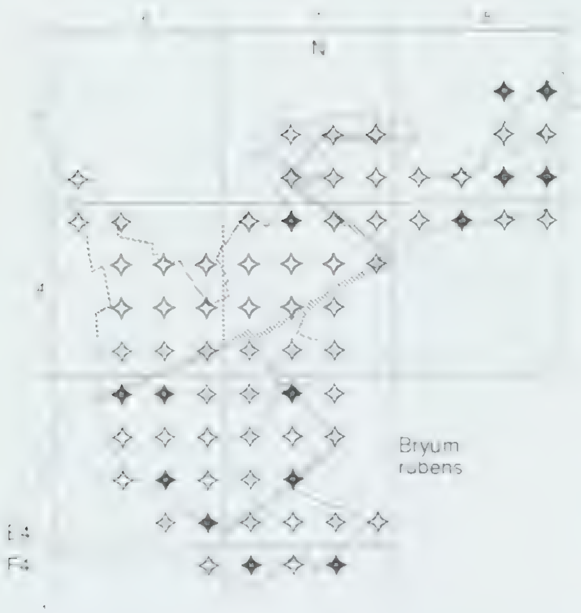
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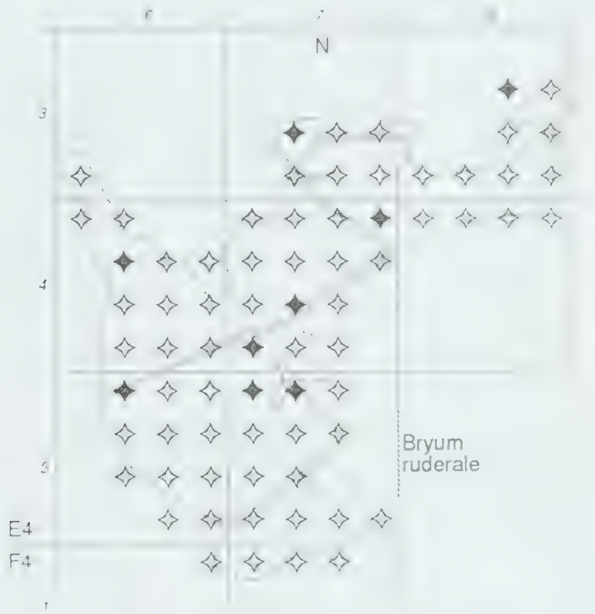
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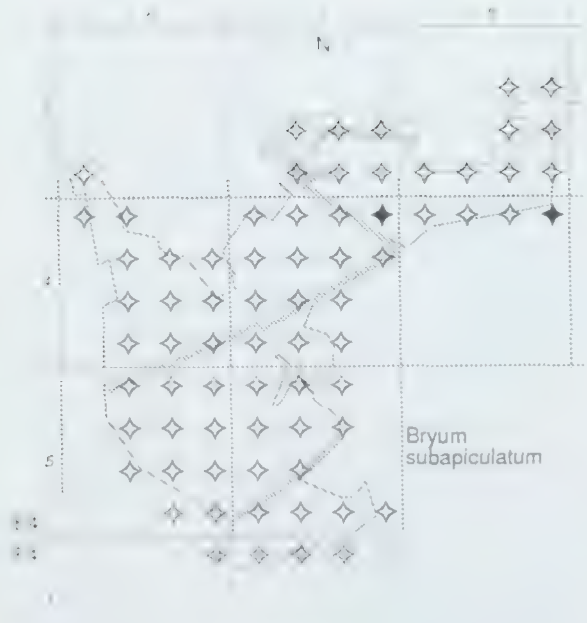
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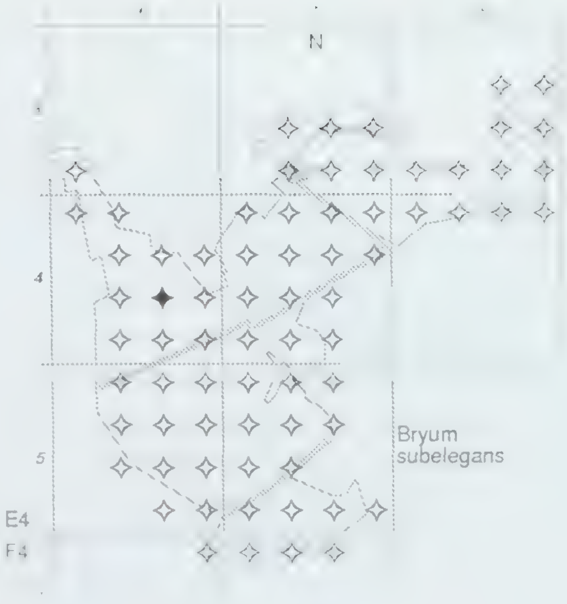
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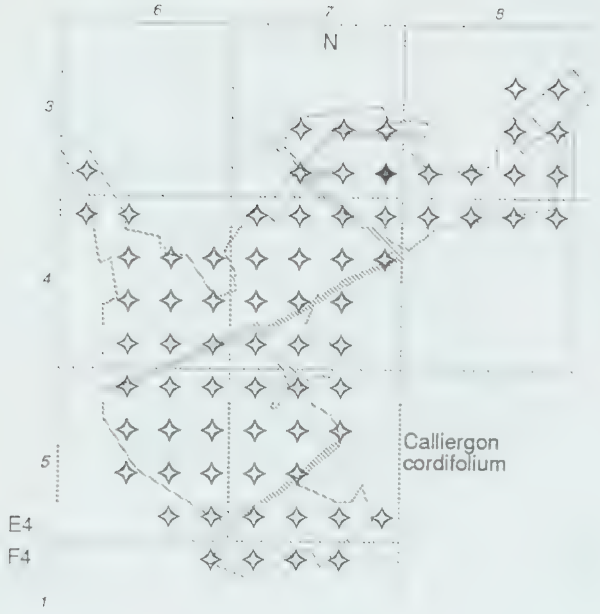
Bryum subelegans



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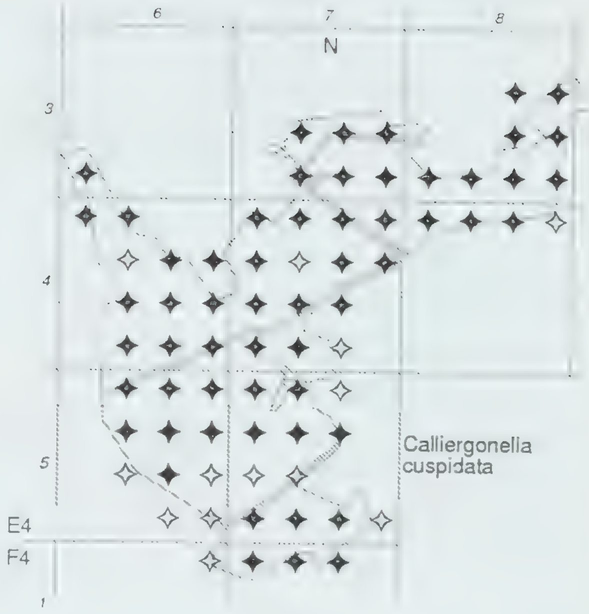

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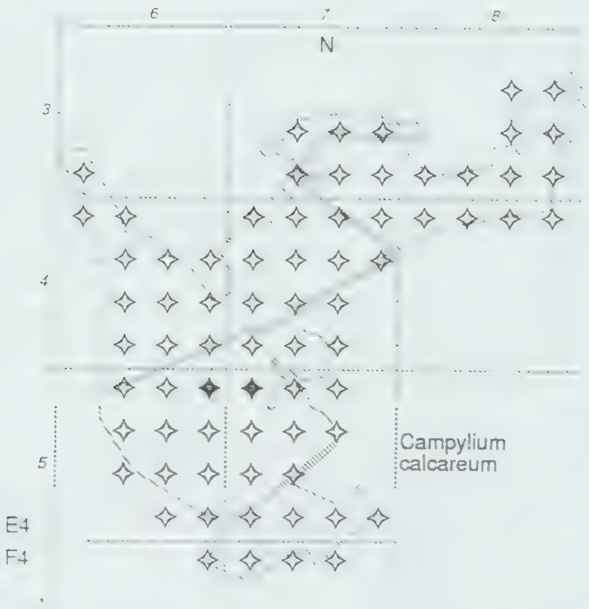
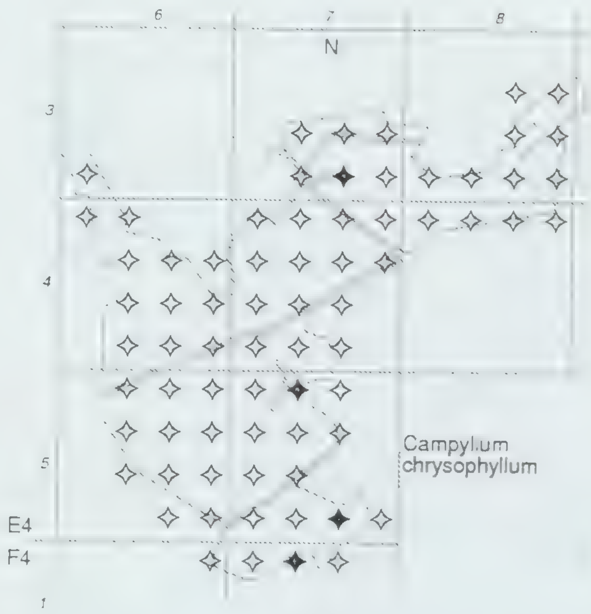


Campylium calcareum



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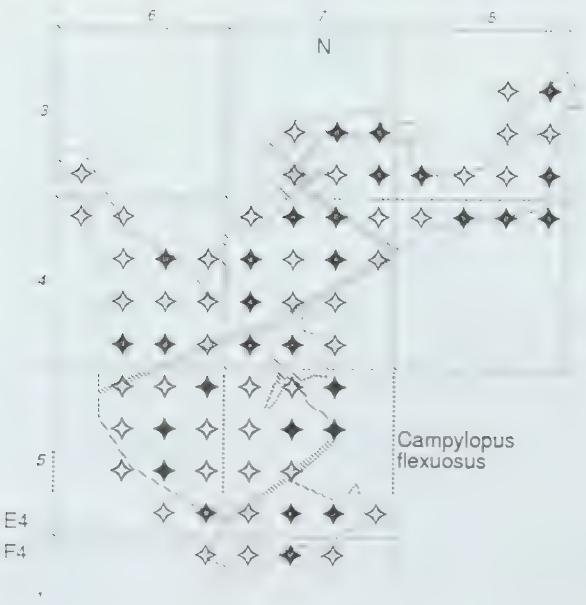

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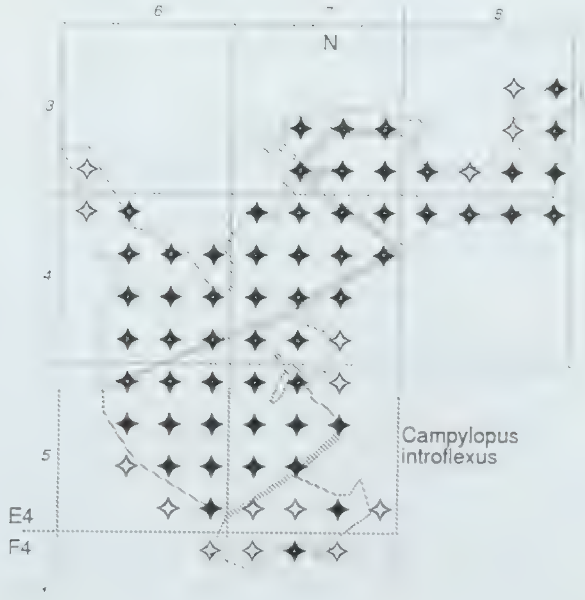

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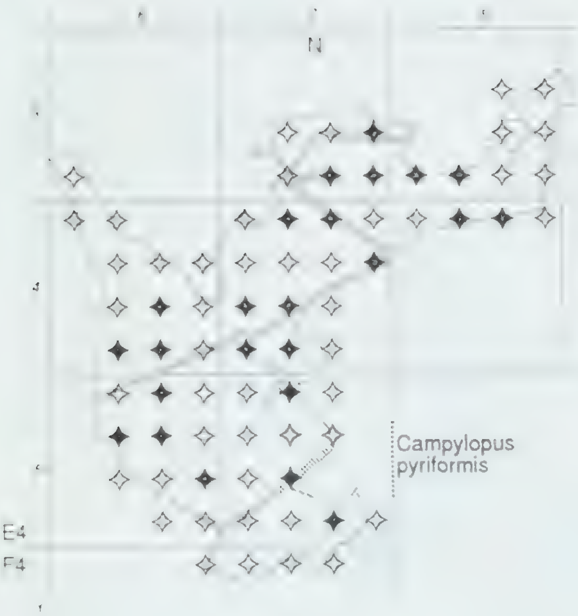

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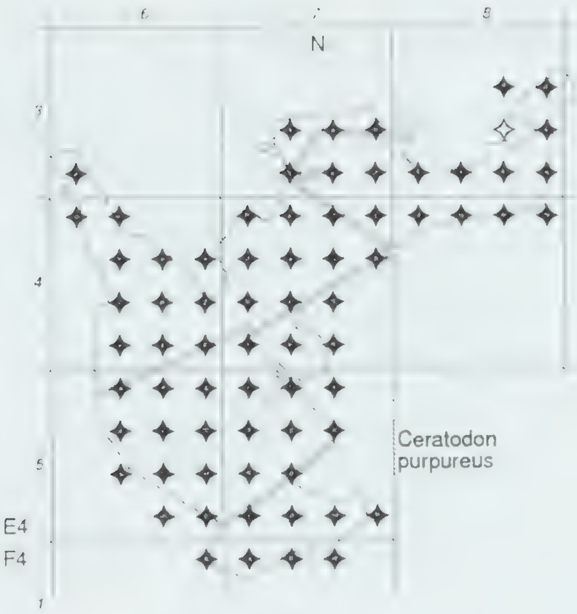

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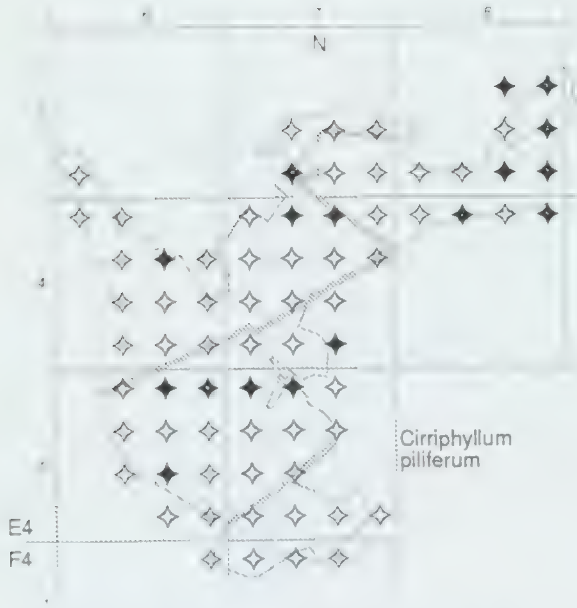
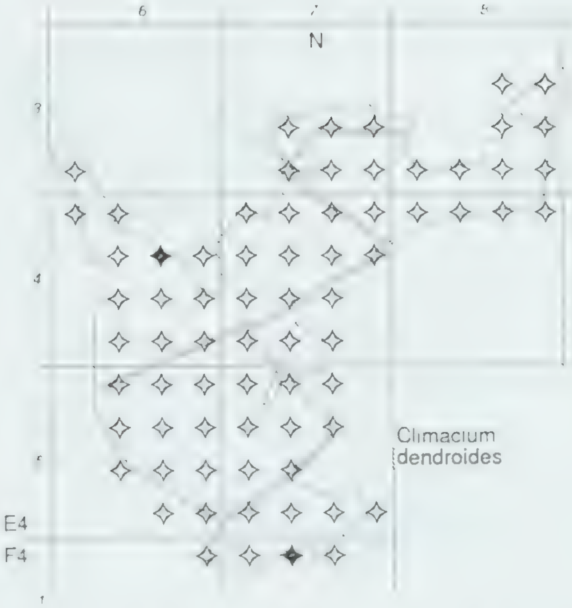
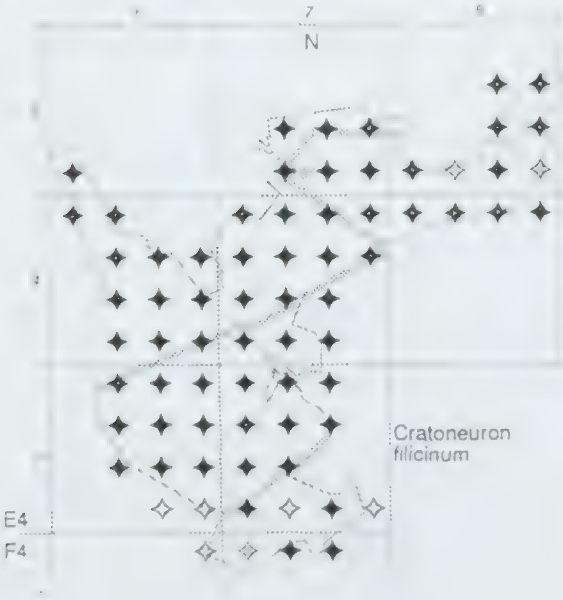


Cirriphyllum piliferum



Climacium dendroides



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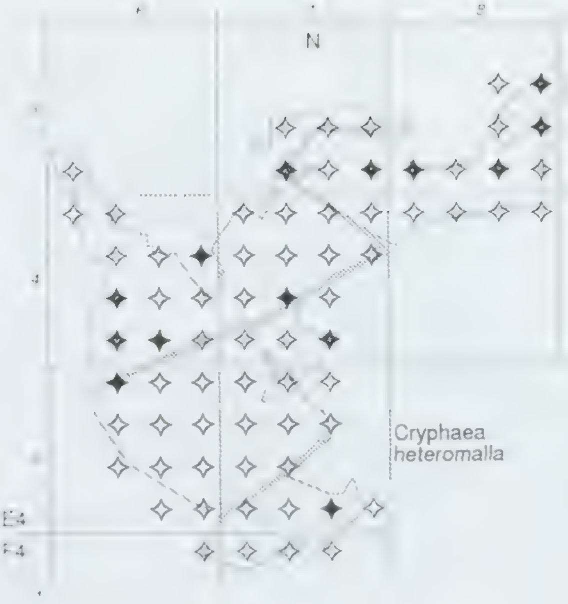
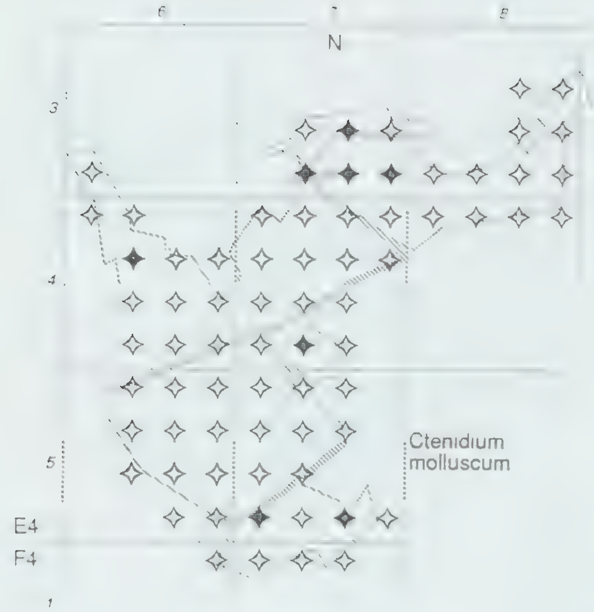
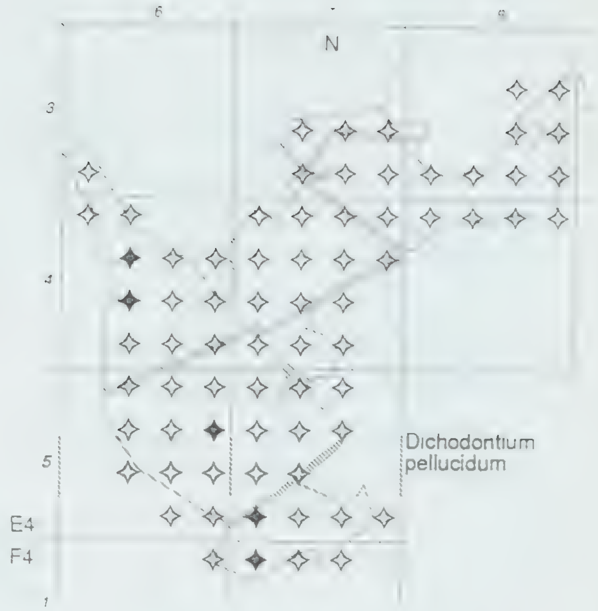


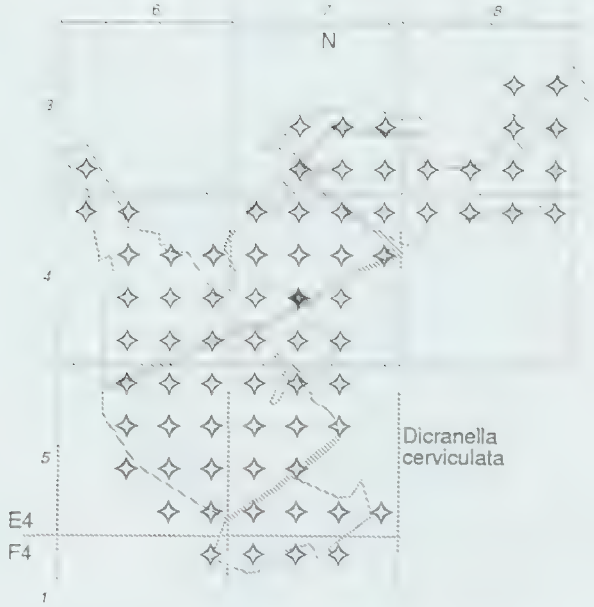
Cryphaea heteromalla



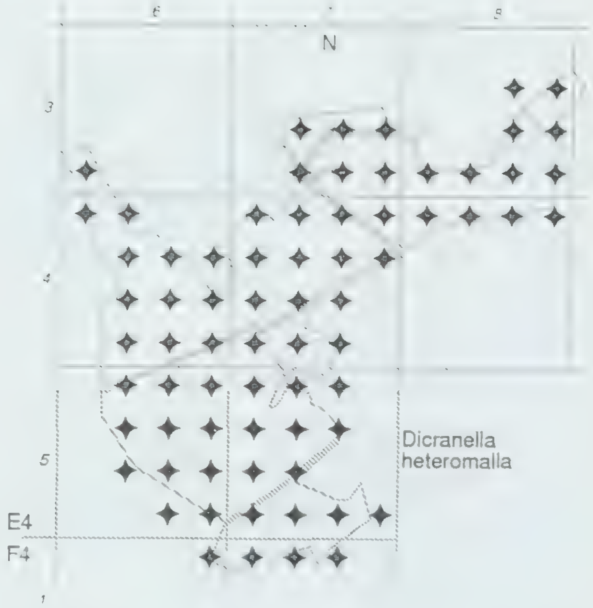
Ctenidium molluscum



Dichodontium pellucidum



Dicranella cerviculata



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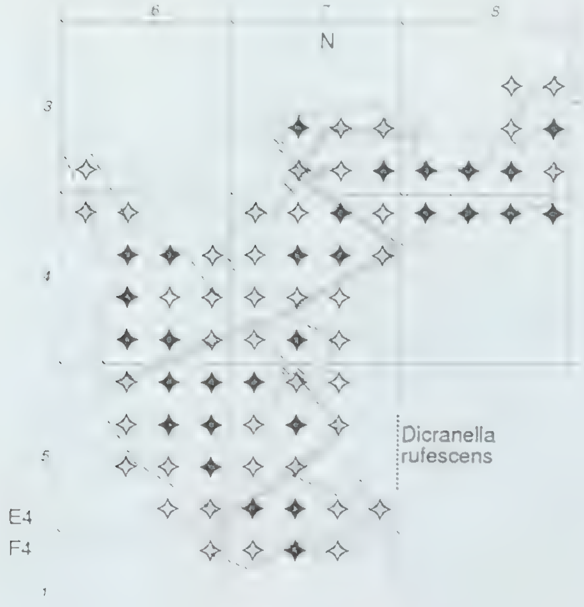

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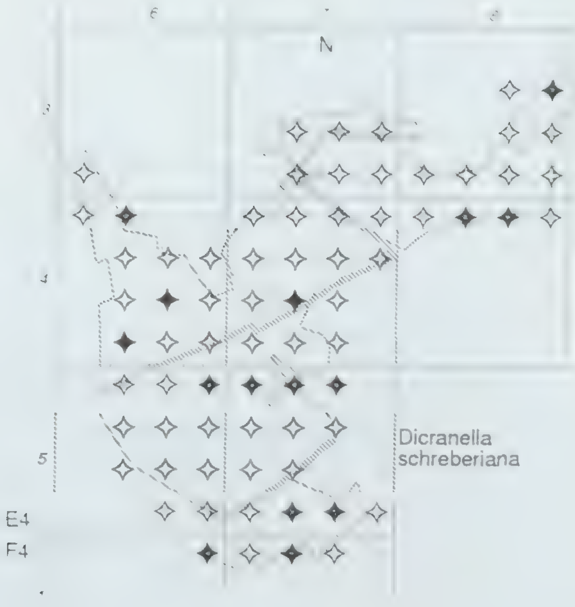

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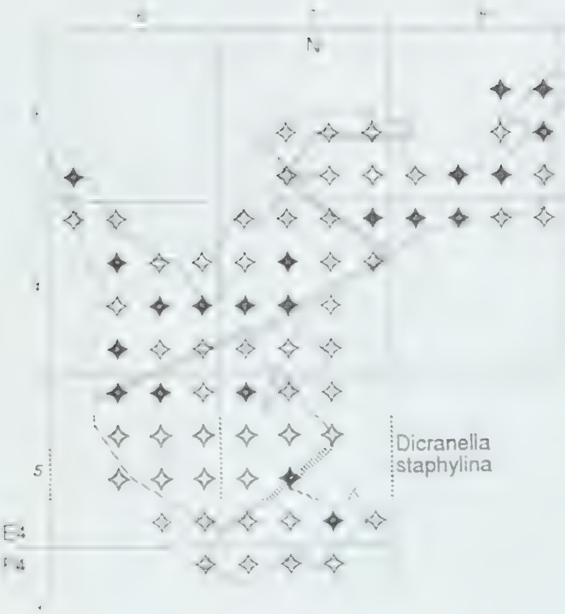

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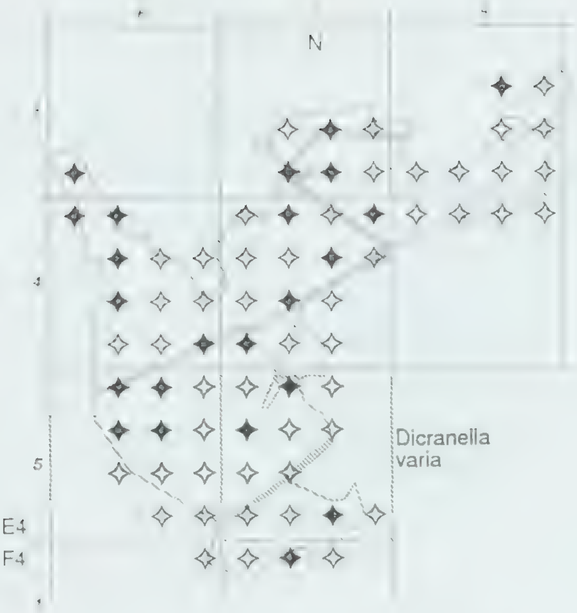

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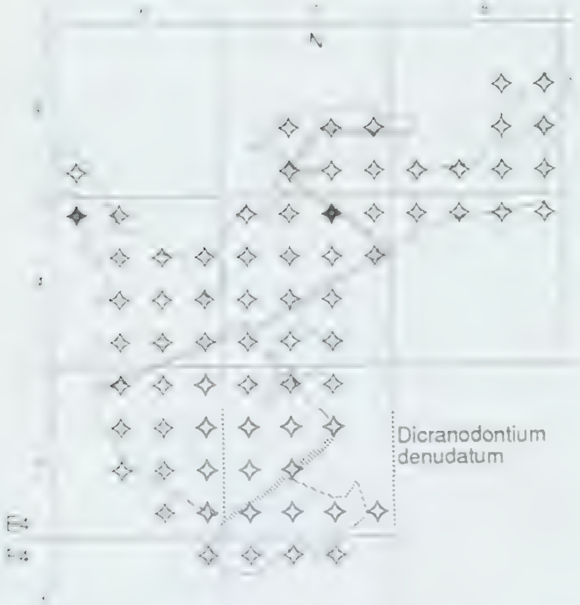

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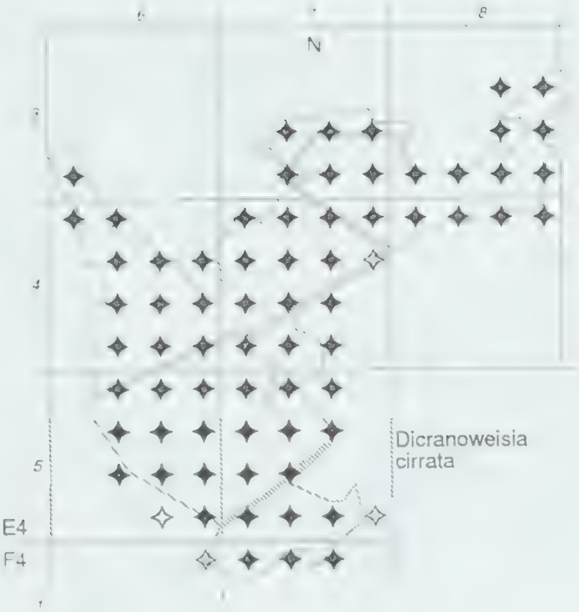
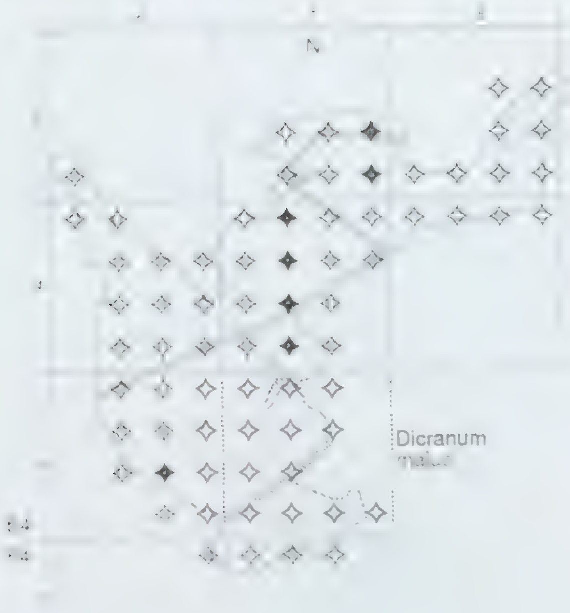
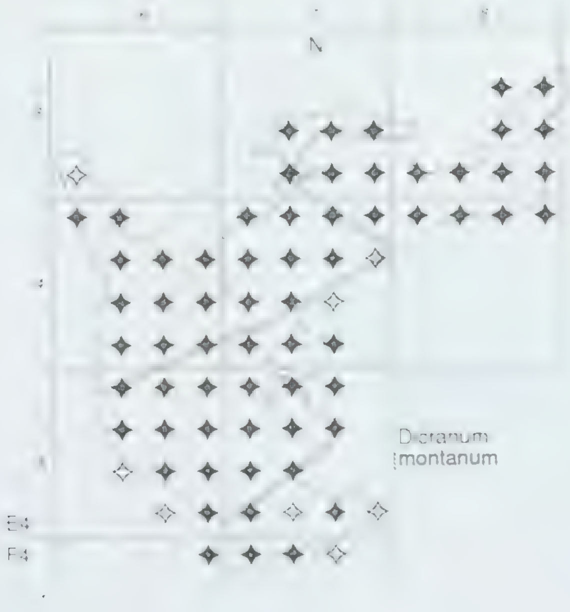


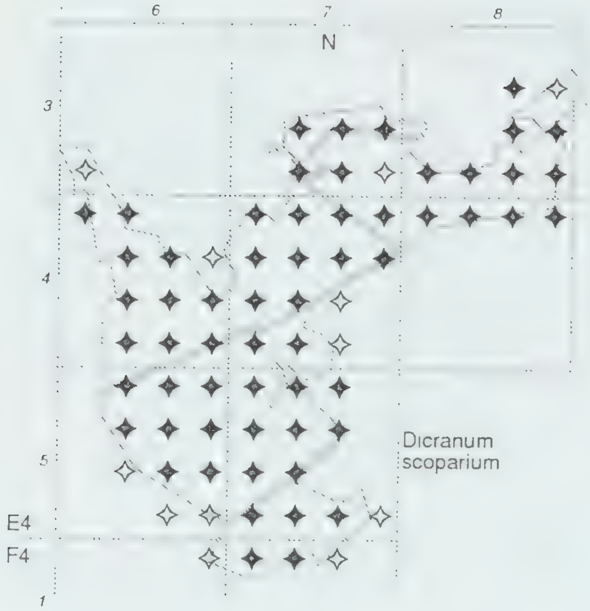
Dicranoweisia cirrata



Dicranum majus



Dicranum montanum



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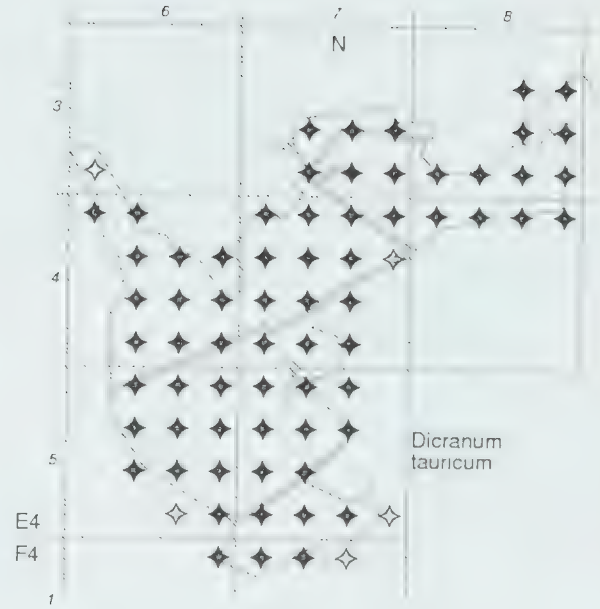

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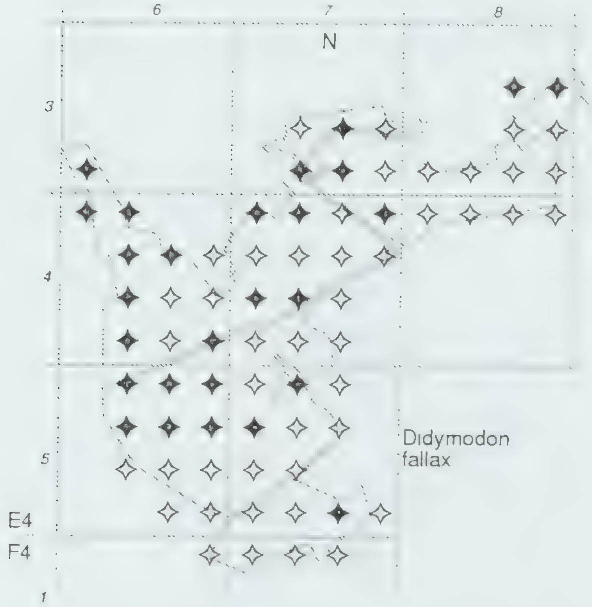
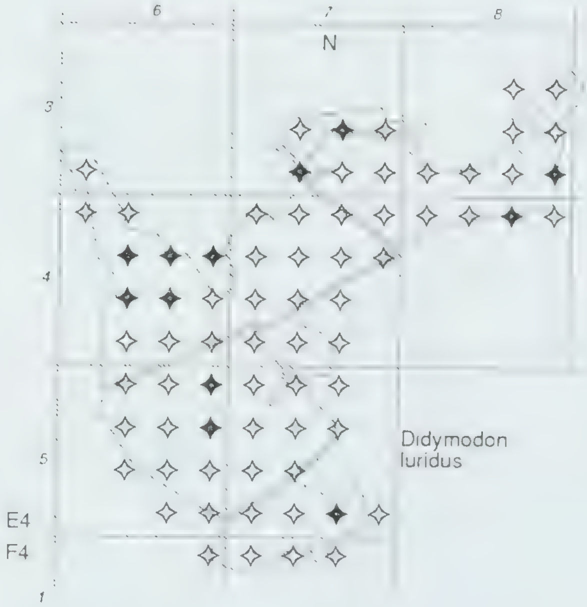
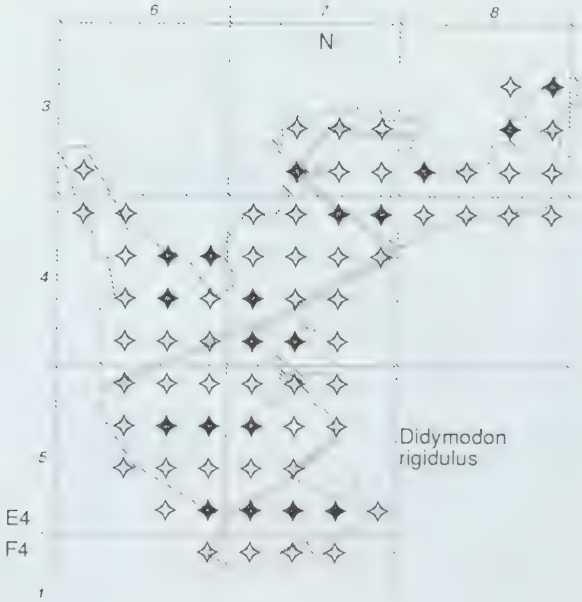


Didymodon fallax



Didymodon luridus



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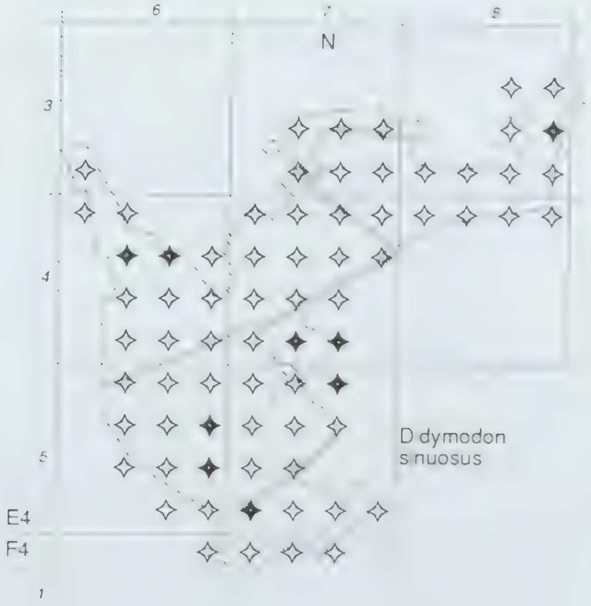

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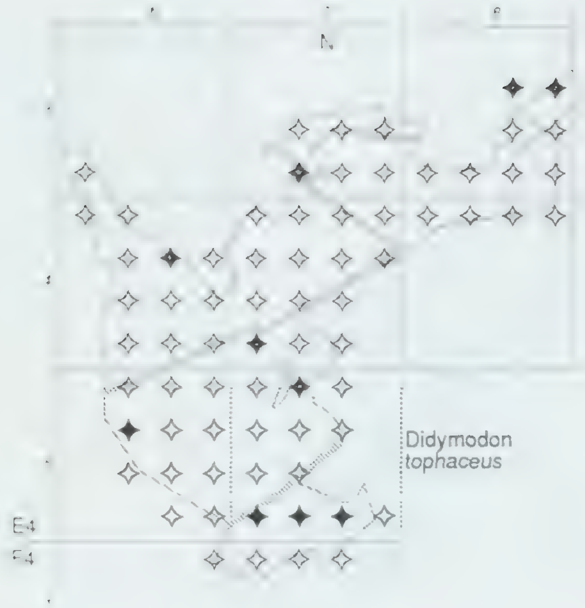

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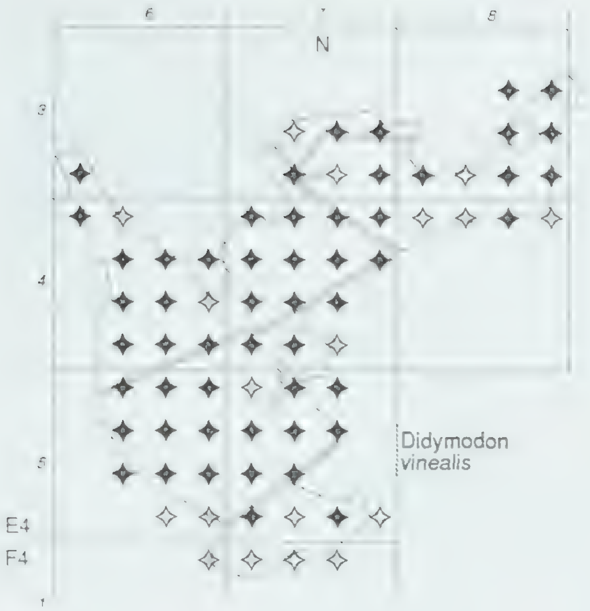

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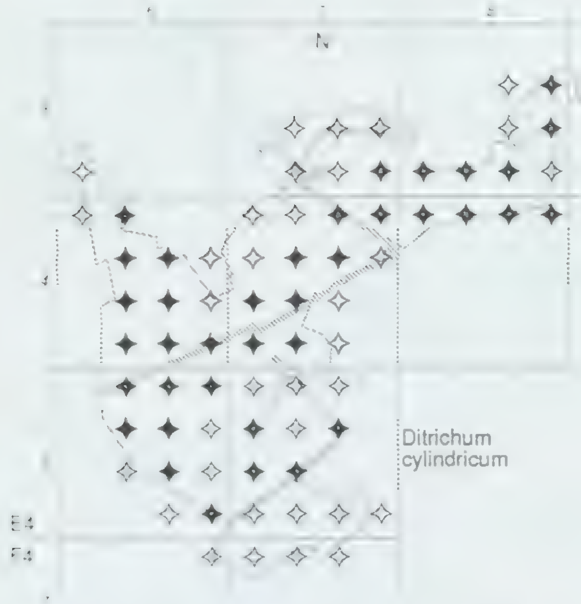
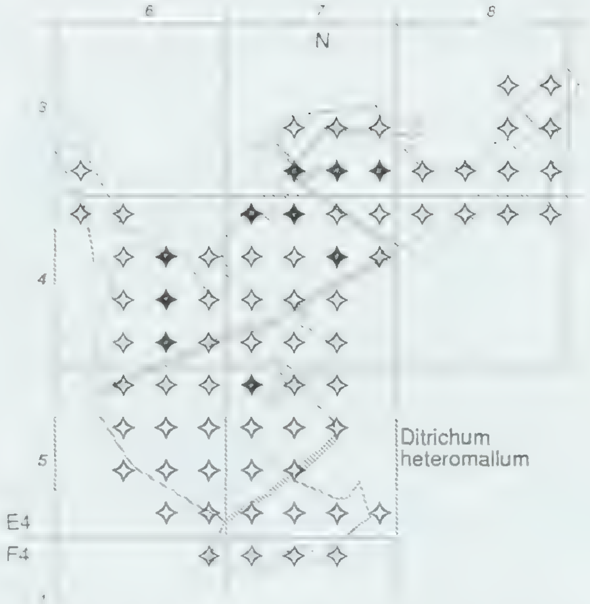


Ditrichum cylindricum



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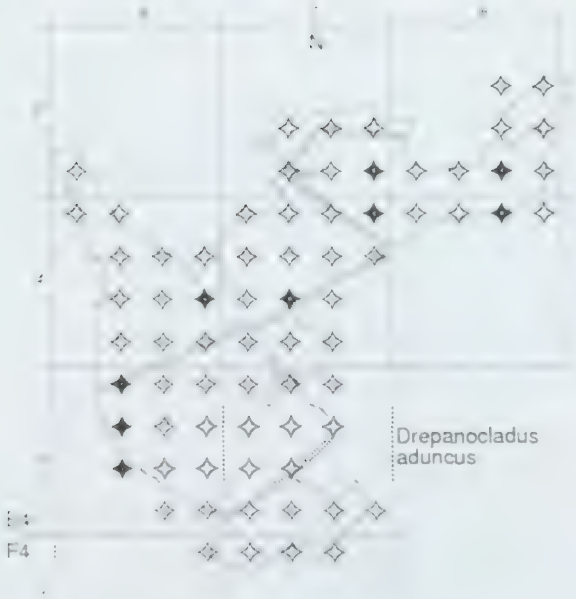

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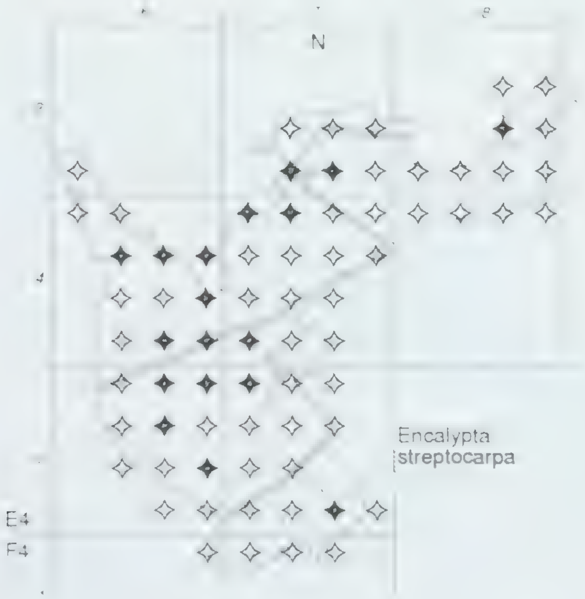
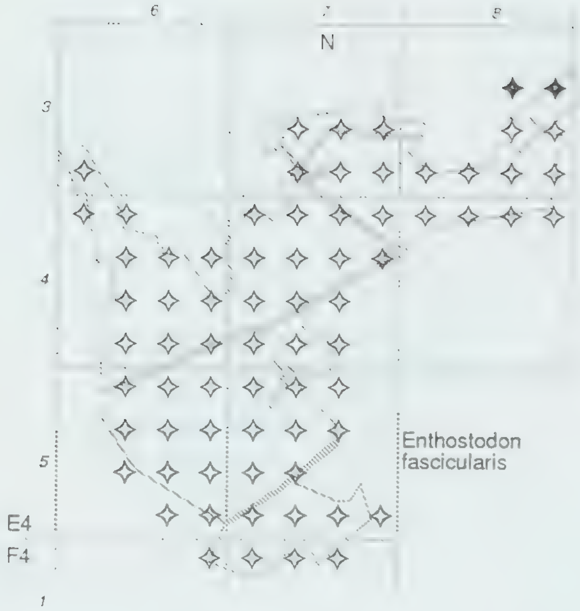


Encalypta streptocarpa



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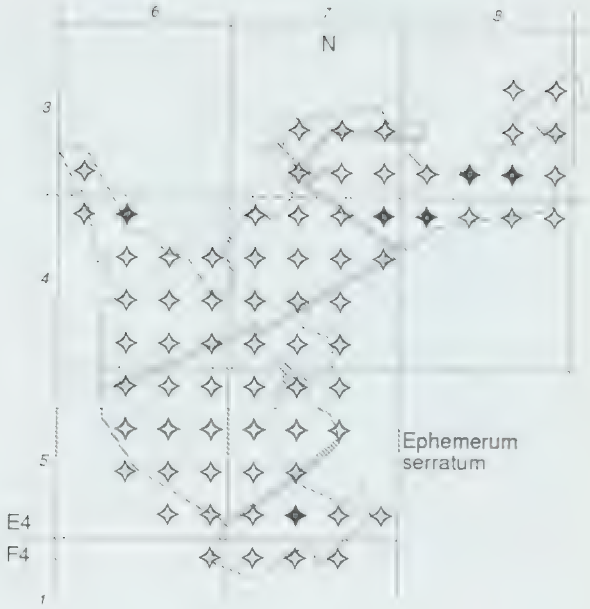

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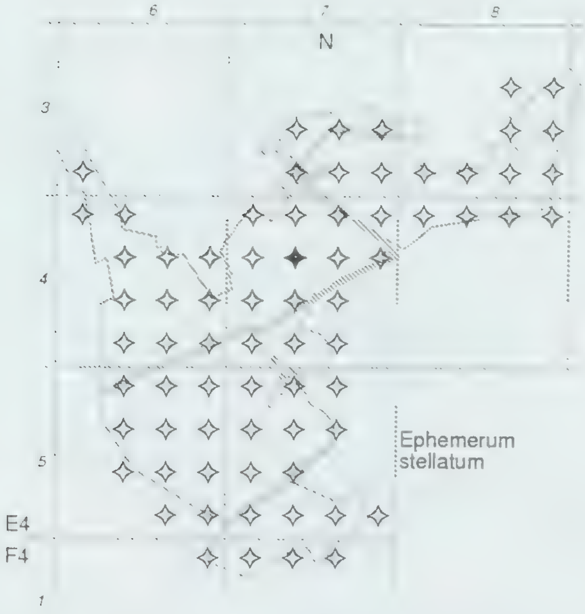
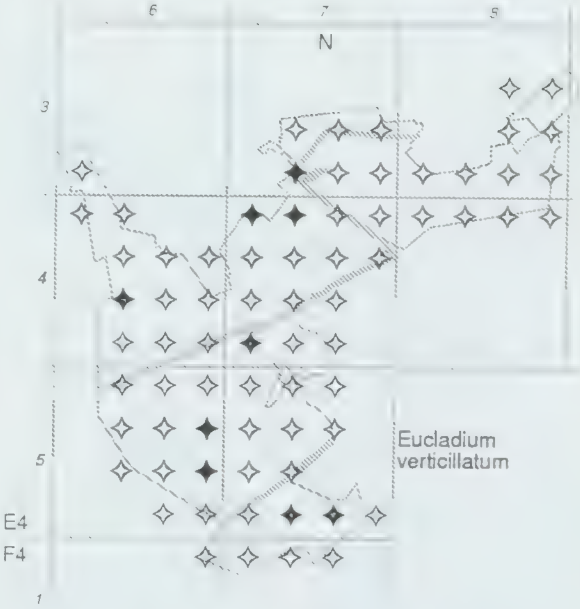


Ephemerum stellatum



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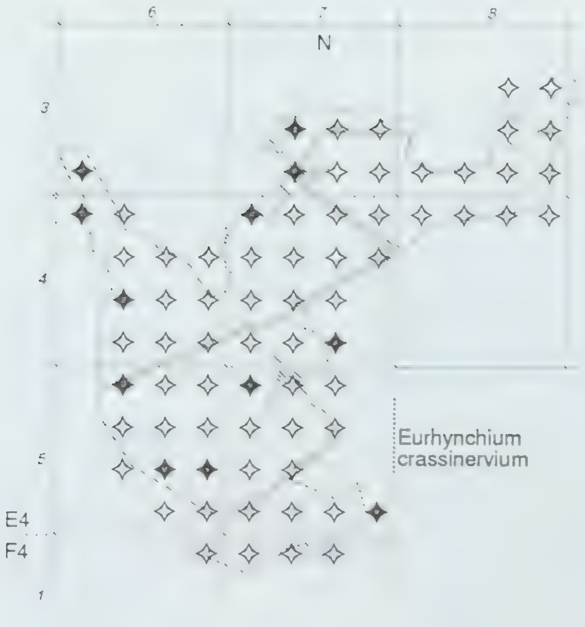
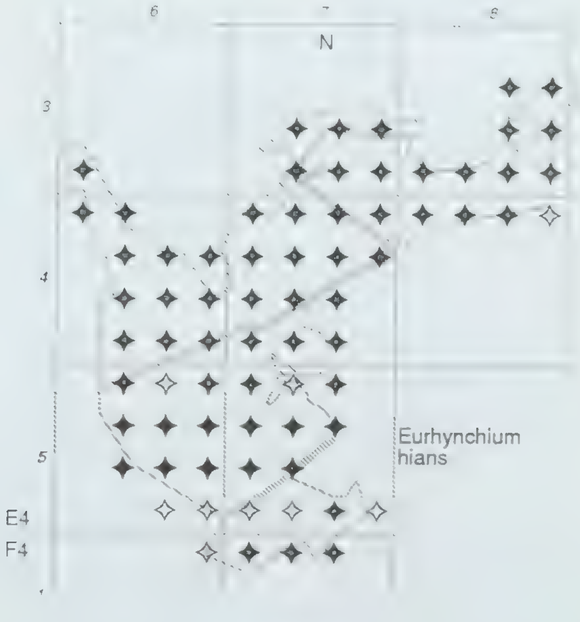


Eurhynchium crassinervium



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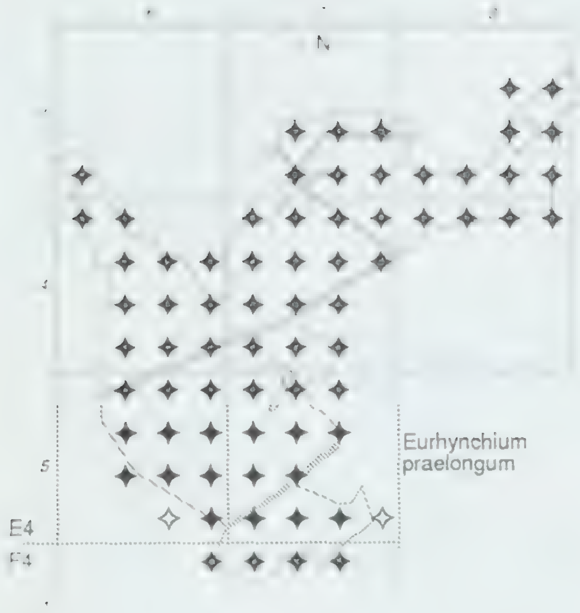

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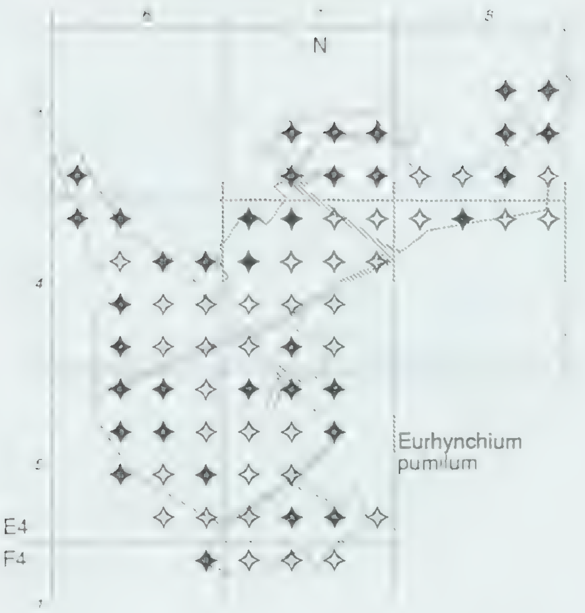
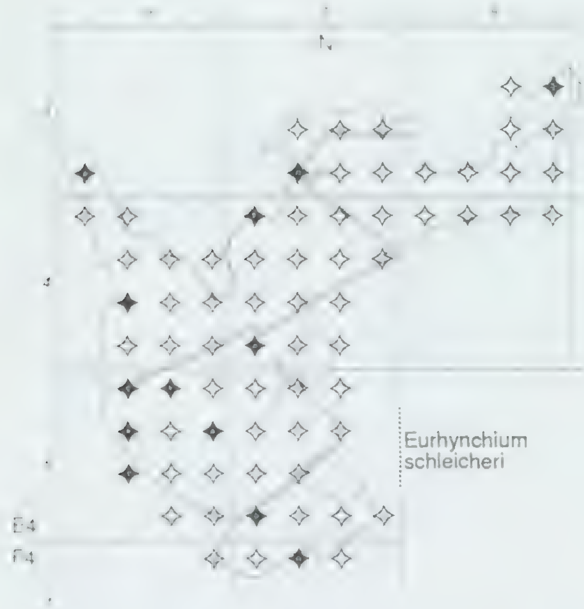


Eurhynchium pumilum



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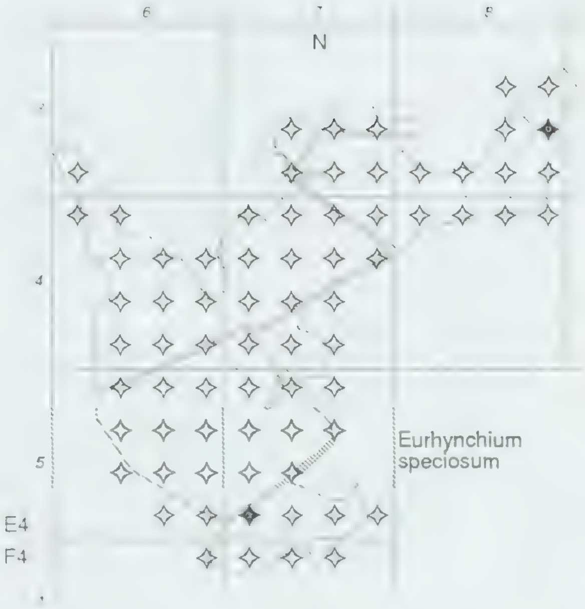

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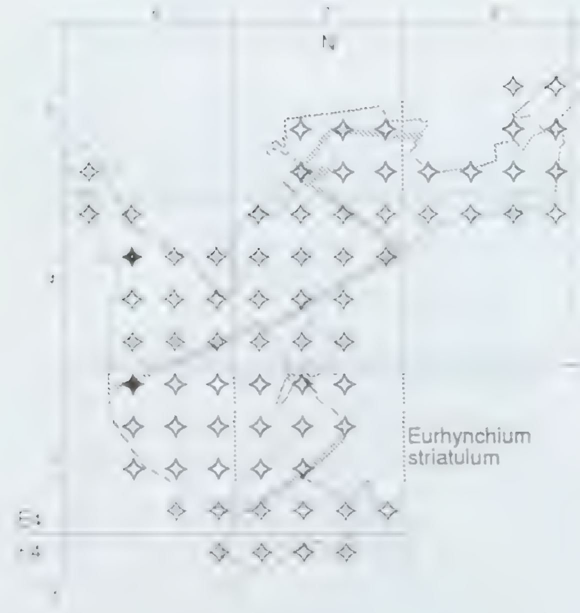

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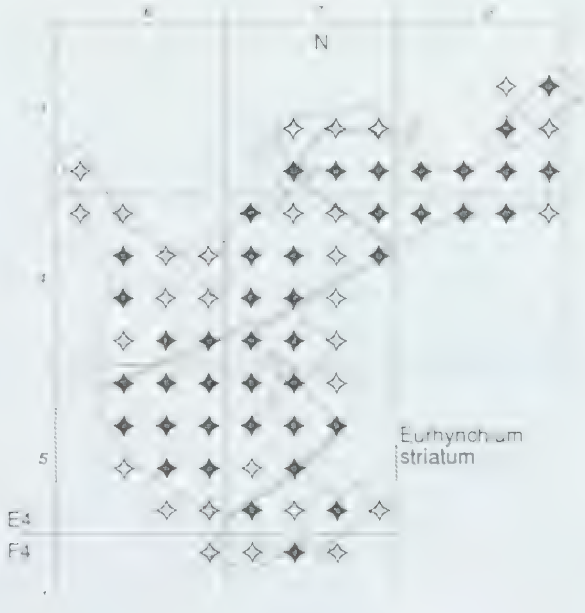
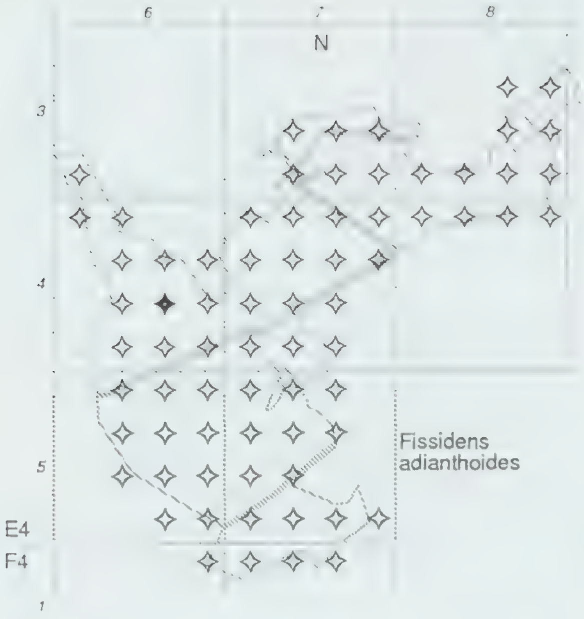
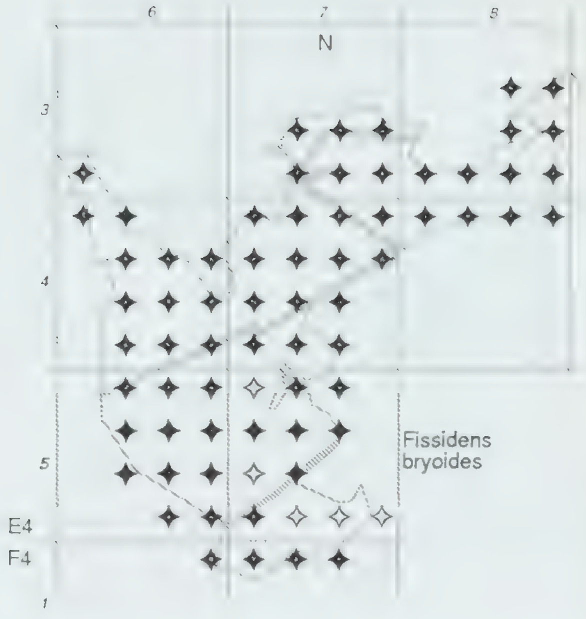


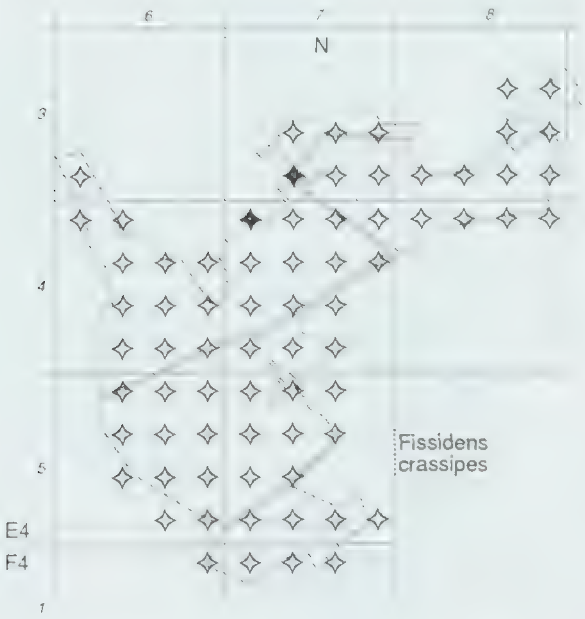
Eurhynchium striatum



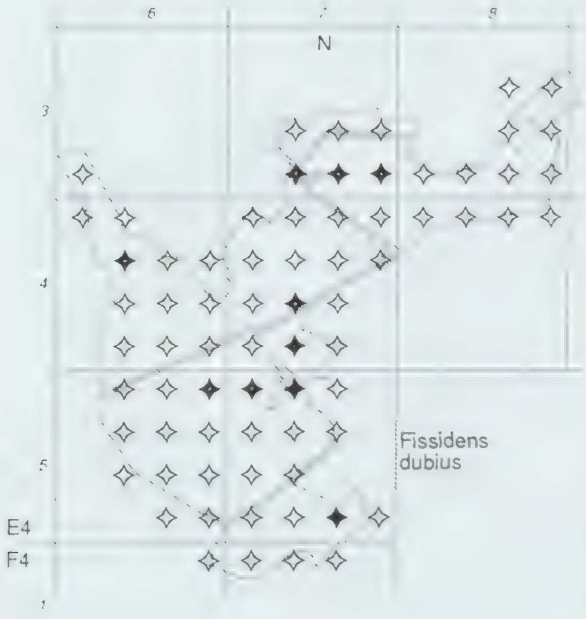
Fissidens adianthoides



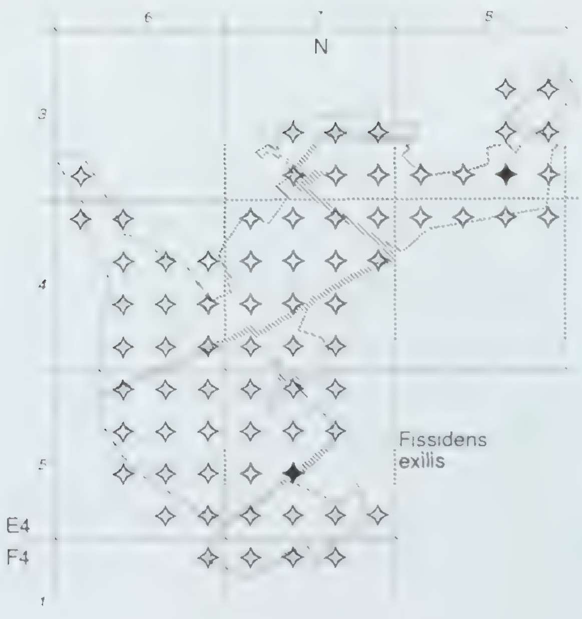
Fissidens bryoides



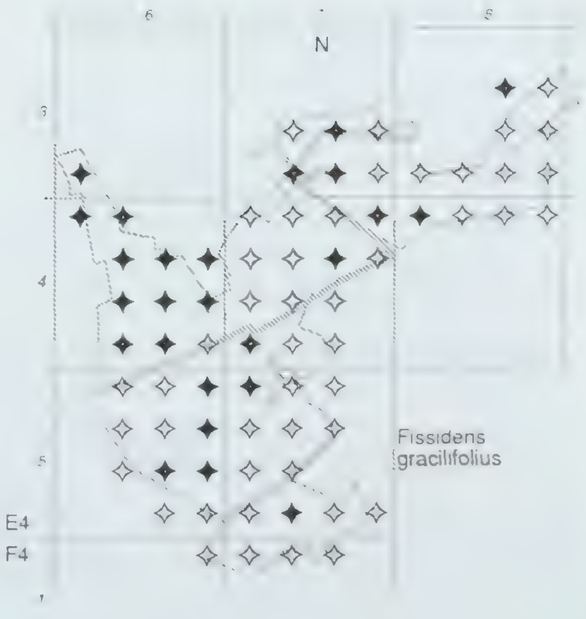
Fissidens crassipes



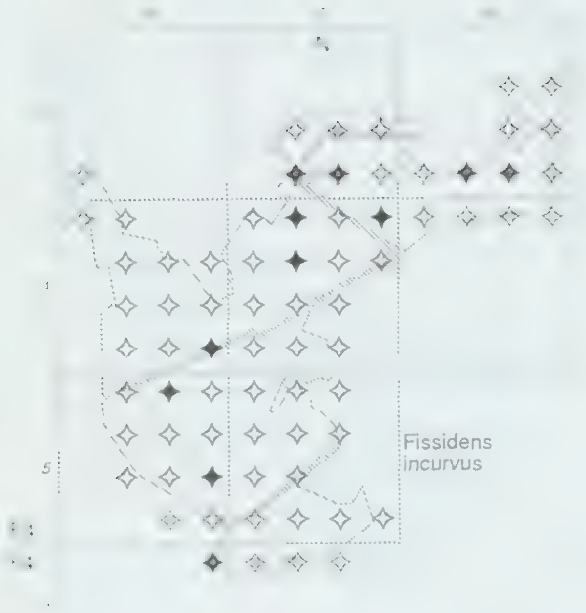
Fissidens dubius



Fissidens exilis



Fissidens gracilifolius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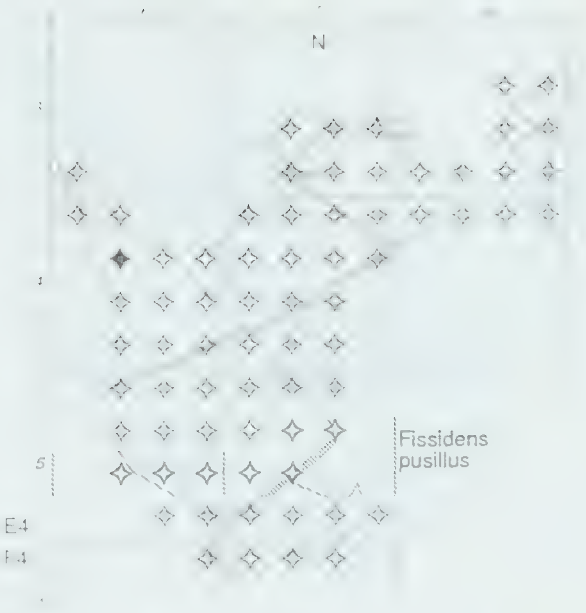
incurvus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E4
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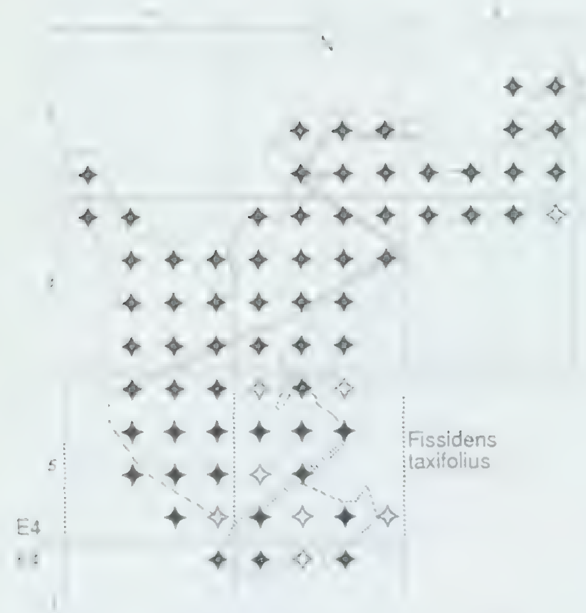
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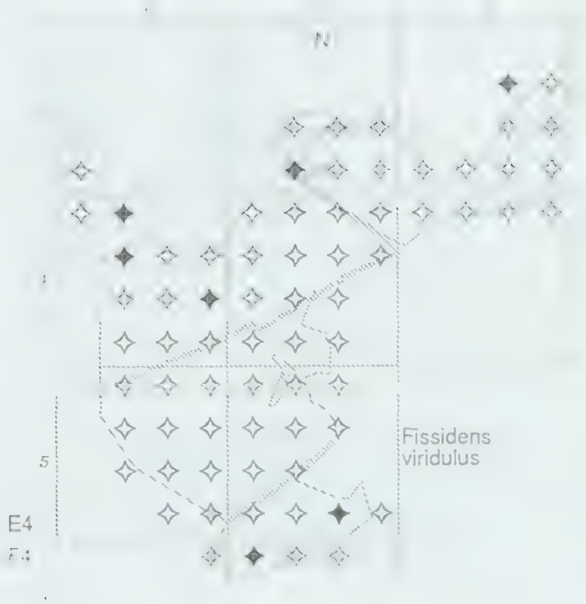
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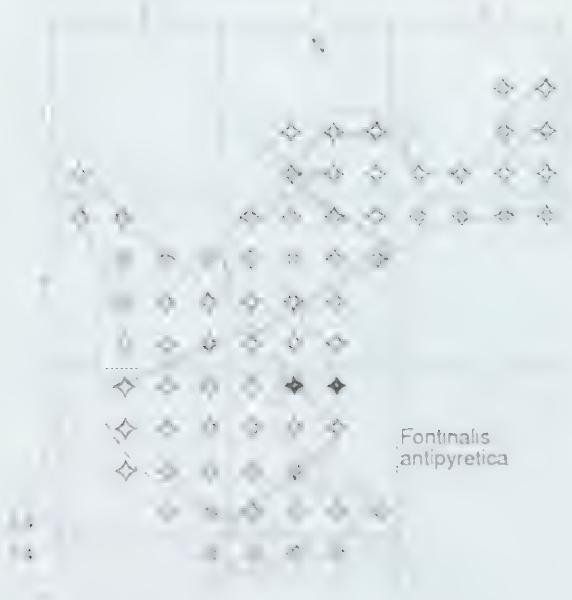
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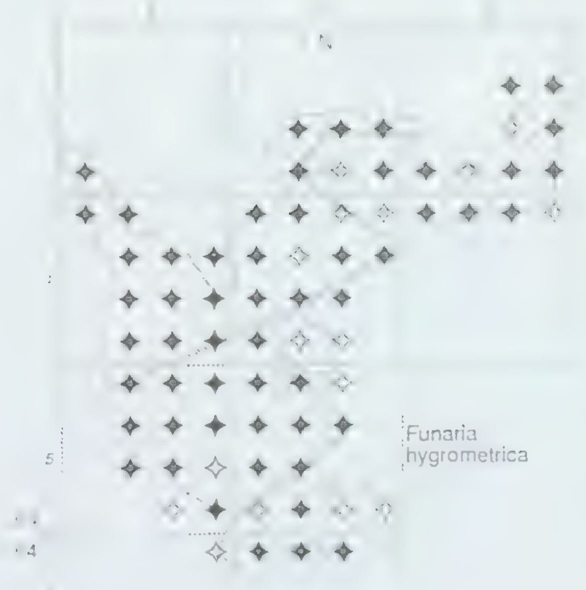
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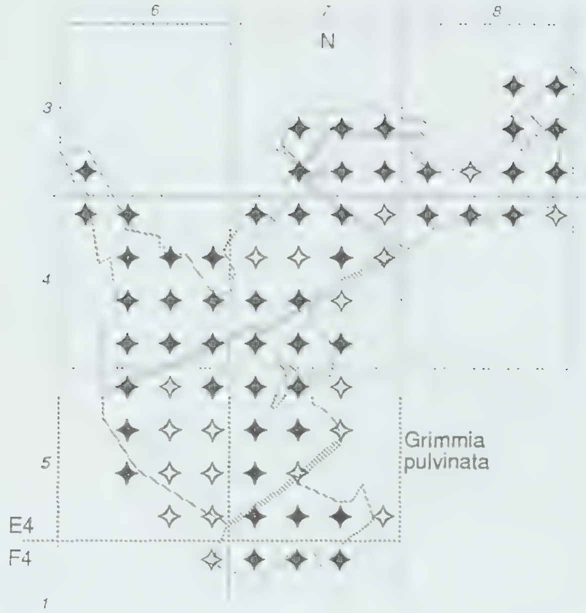
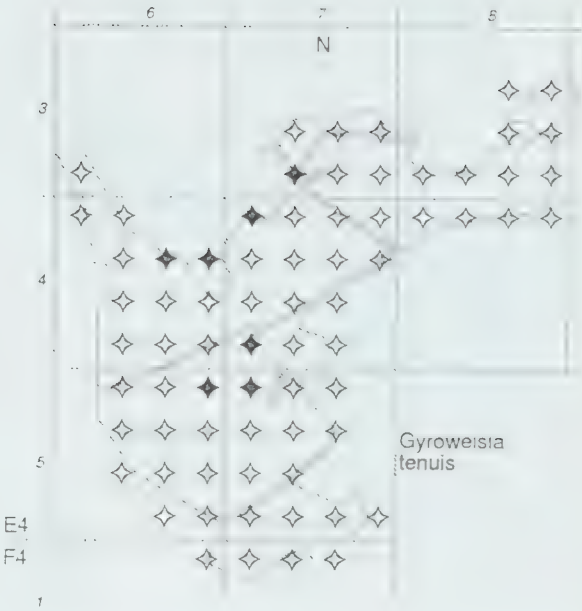
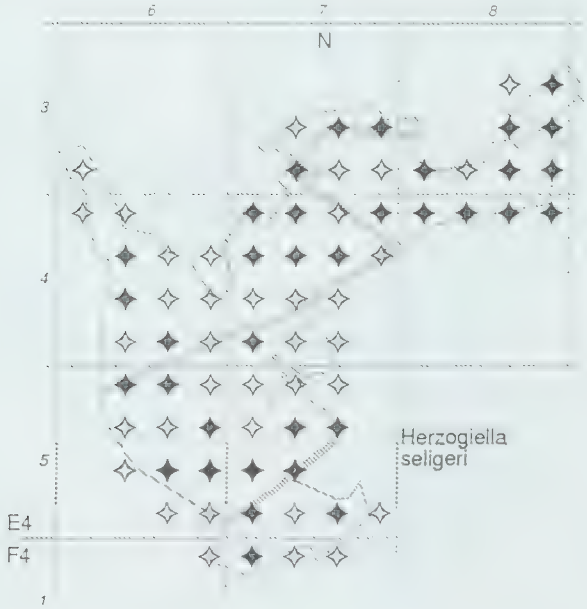


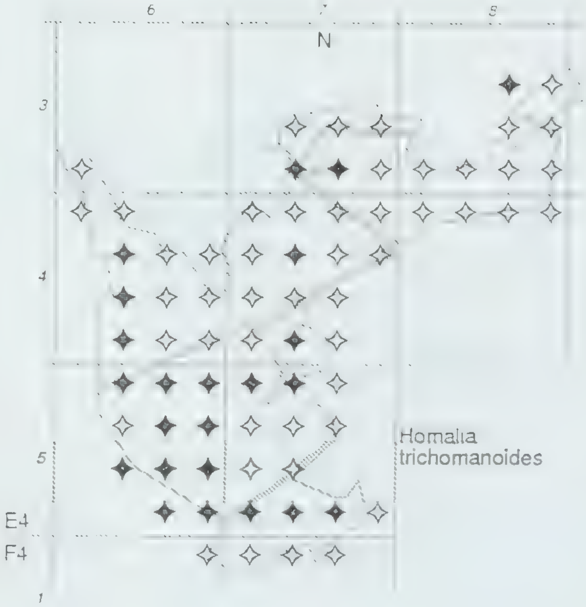
Grimmia pulvinata



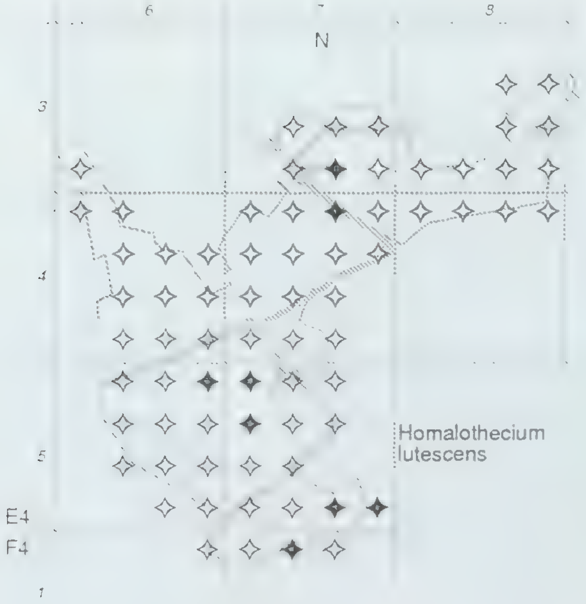
Gyroweisia tenuis



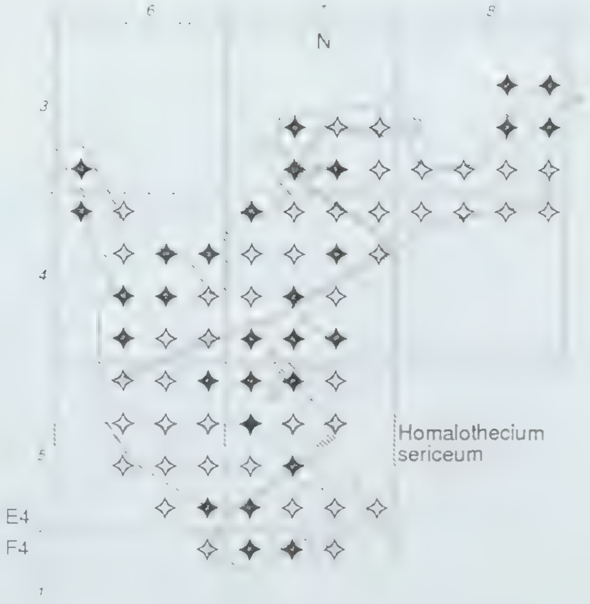
Herzogiella seligeri



Homalia trichomanoides



Homalothecium lutescens



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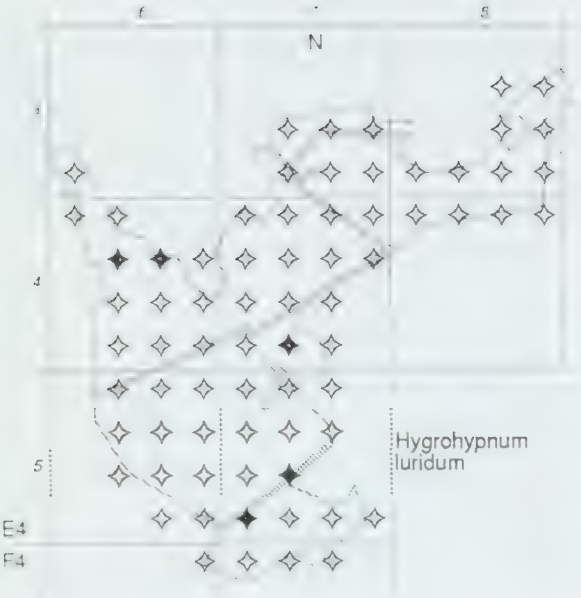

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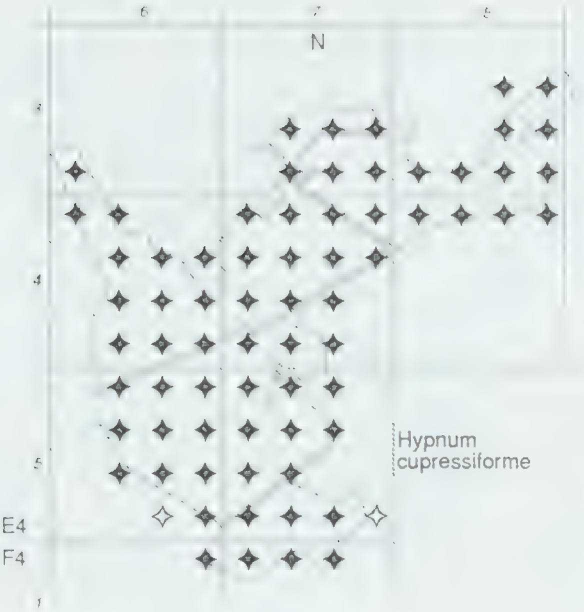
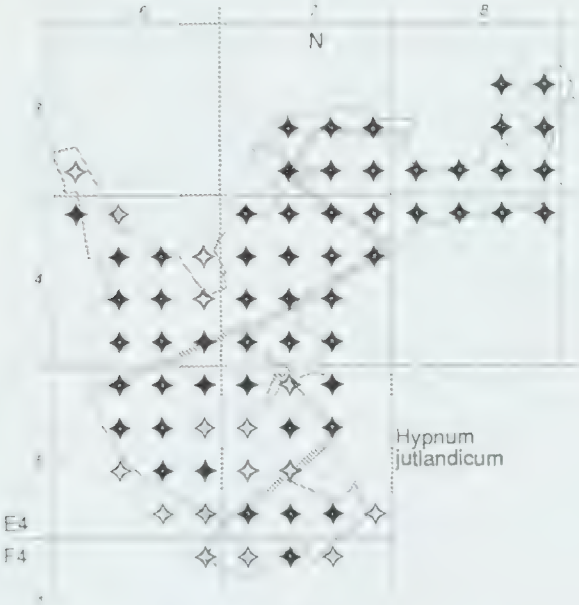
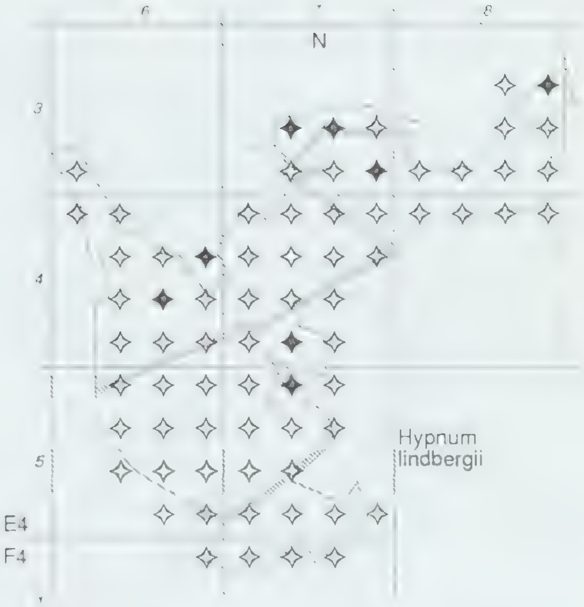


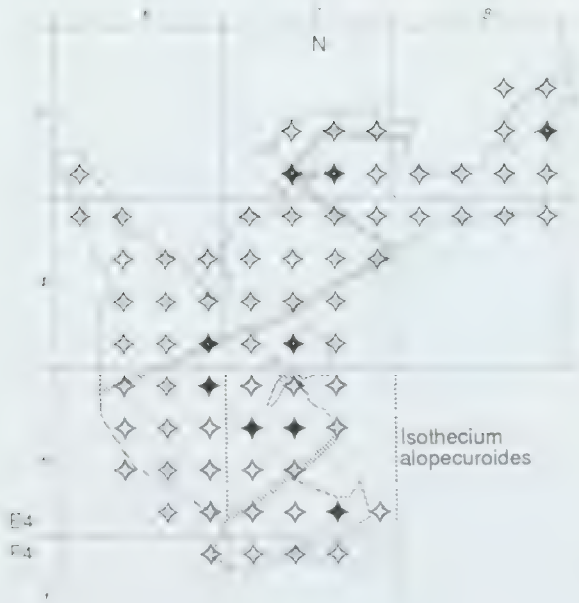
Hypnum cupressiforme



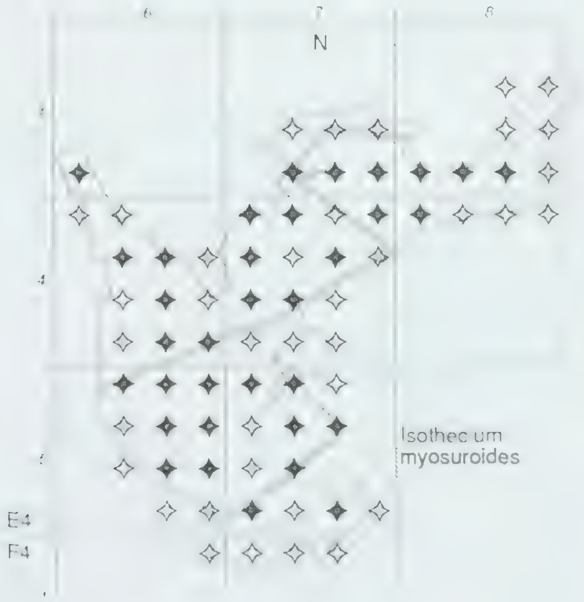
Hypnum jutlandicum



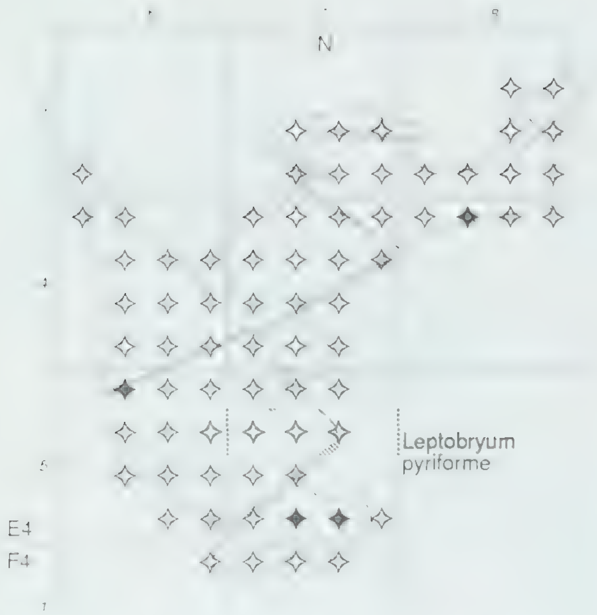
Hypnum lindbergii



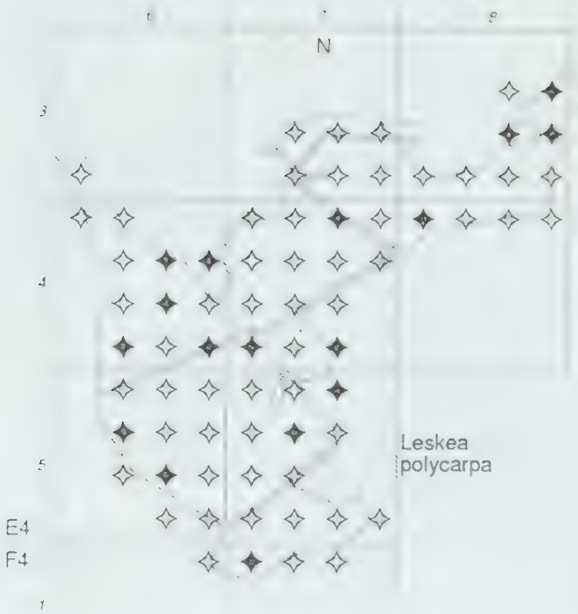
Isothecium alopecuroides



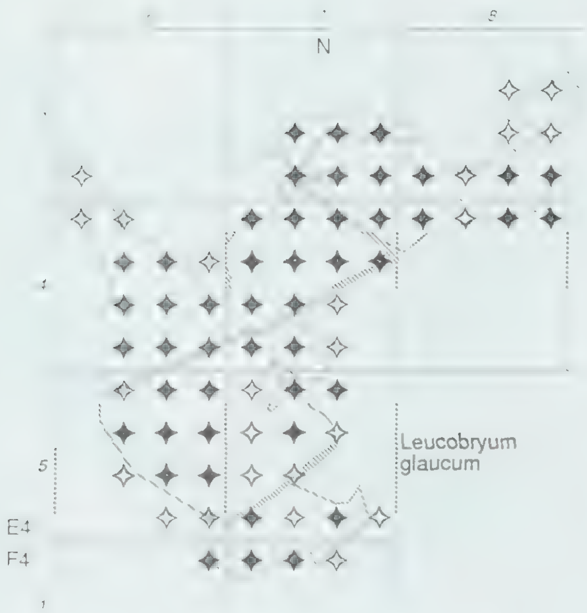
Isothecium myosuroides



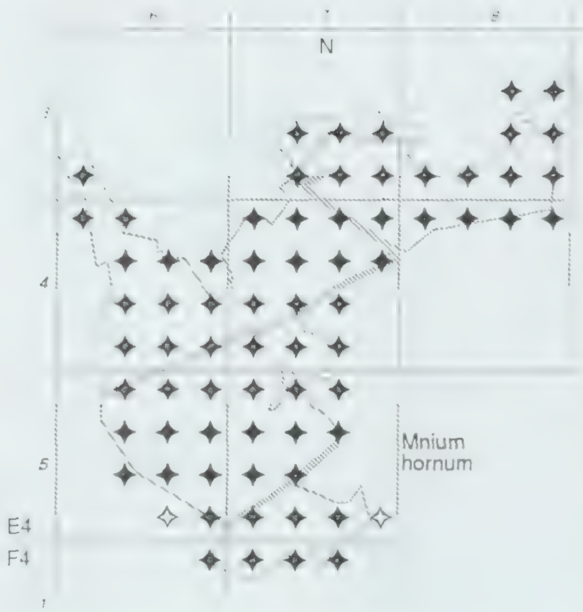
Leptobryum pyriforme



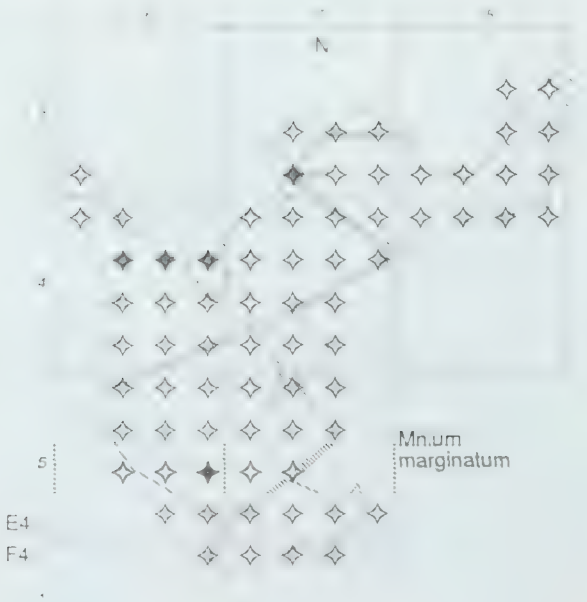
Leskea polycarpa



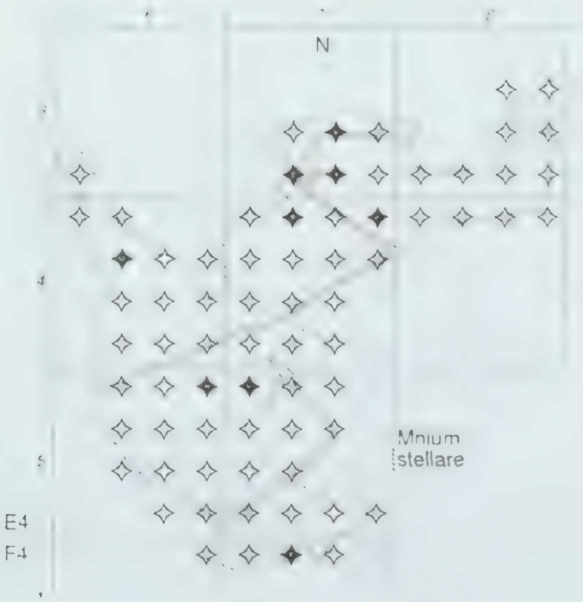
Leucobryum glaucum



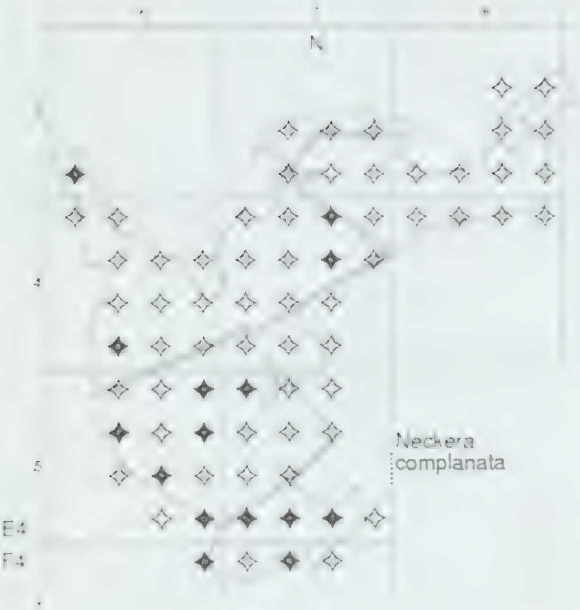
Mnium hornum



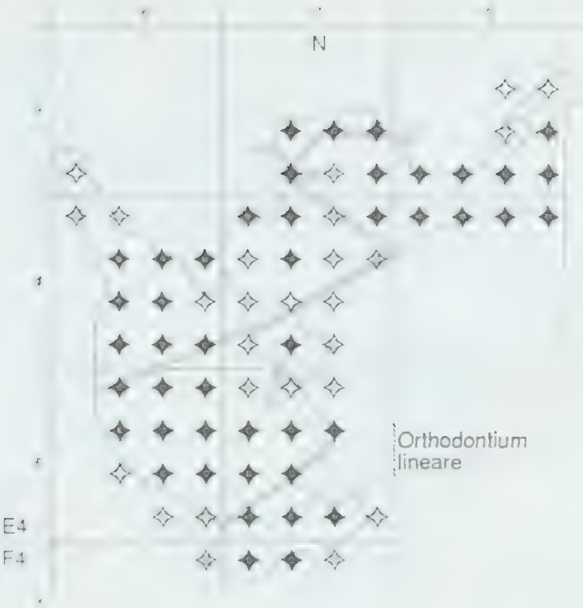
Mnium marginatum



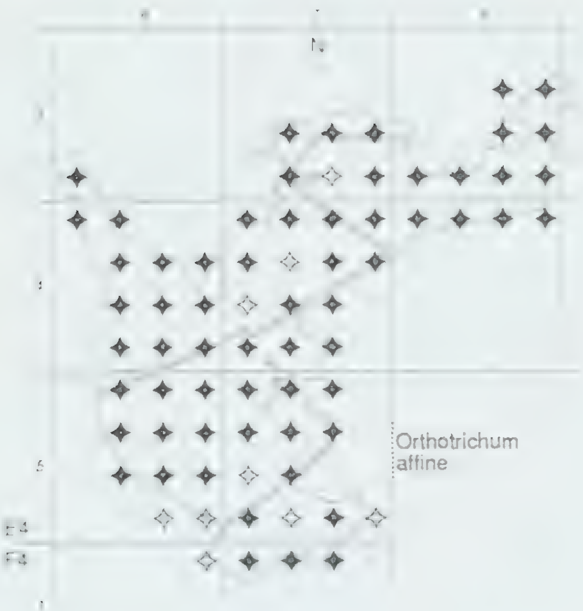
Mnium stellare



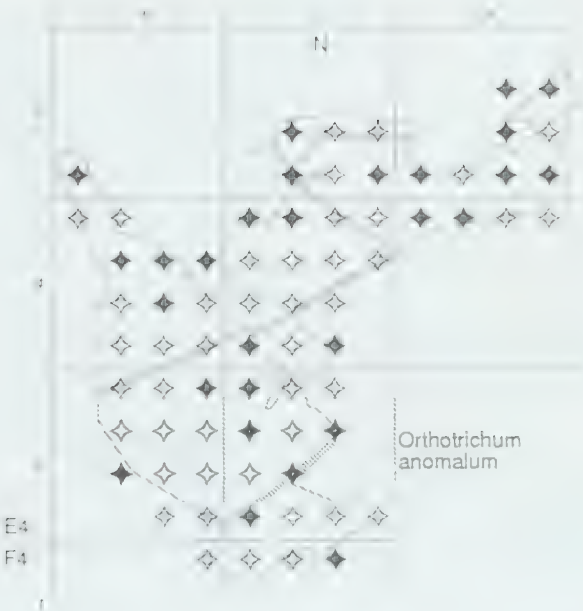
Neckera complanata



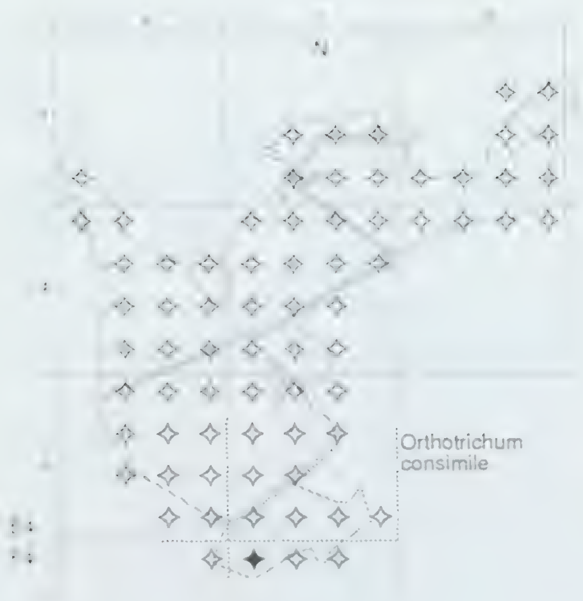
Orthodontium lineare



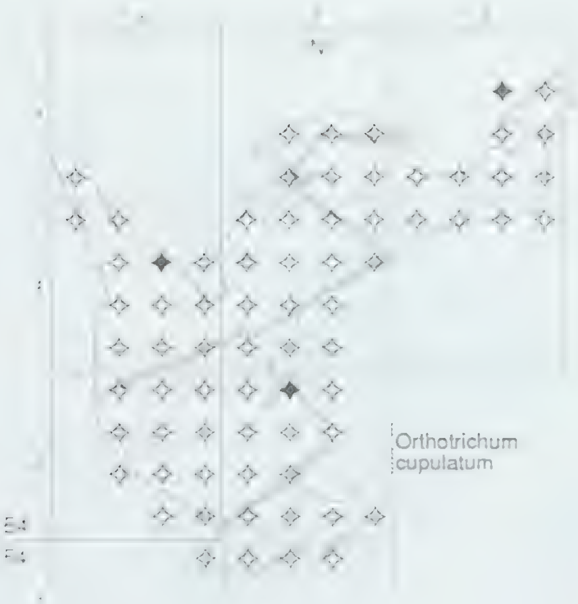
Orthotrichum affine



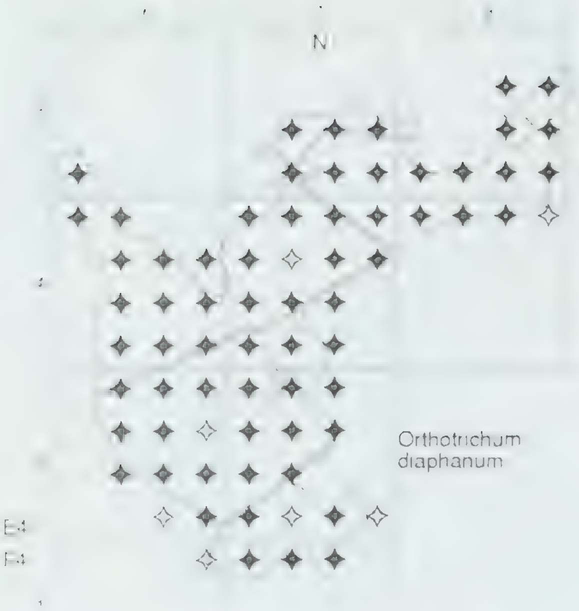
Orthotrichum anomalum



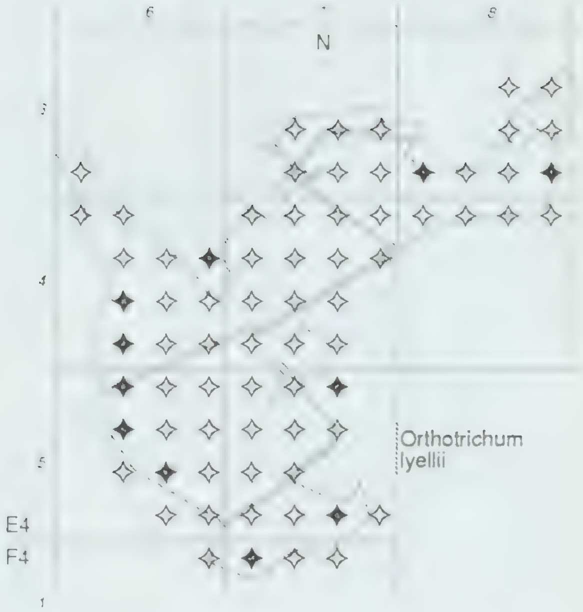
Orthotrichum consimile



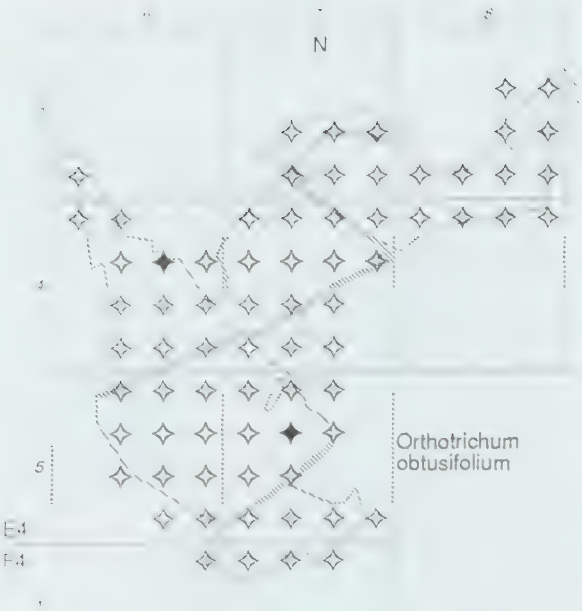
Orthotrichum cupulatum



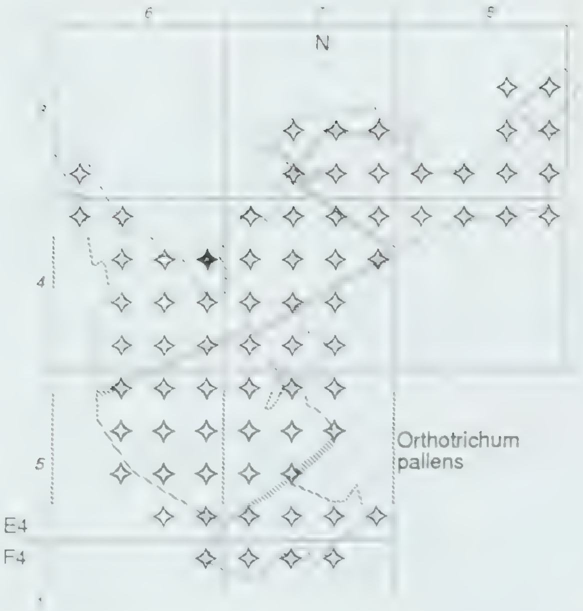
Orthotrichum diaphanum



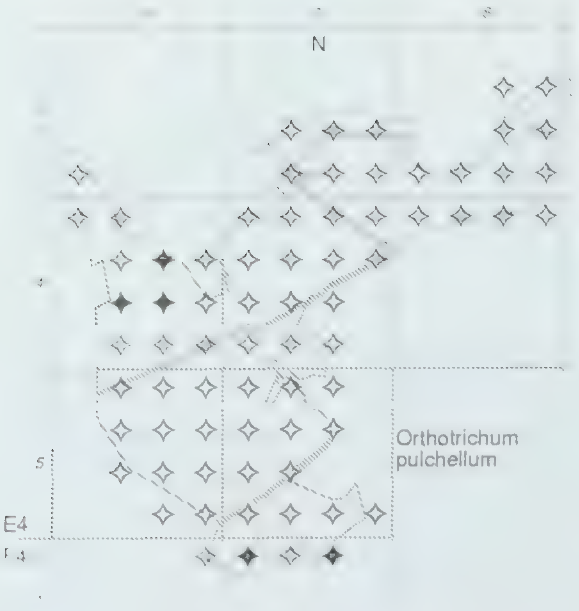
Orthotrichum lyellii



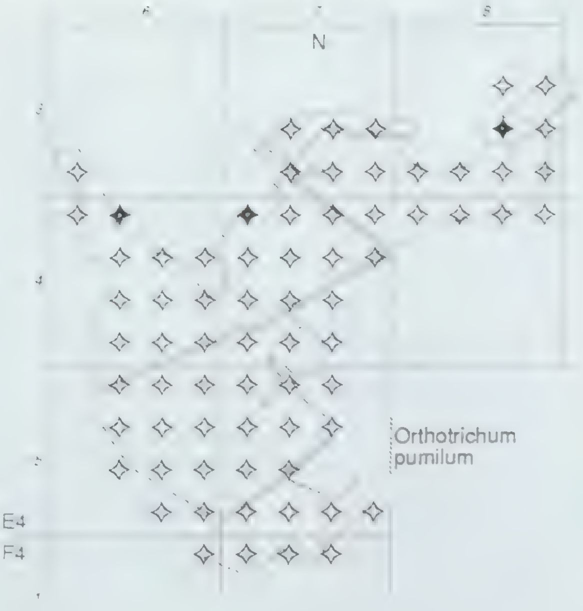
Orthotrichum obtusifolium



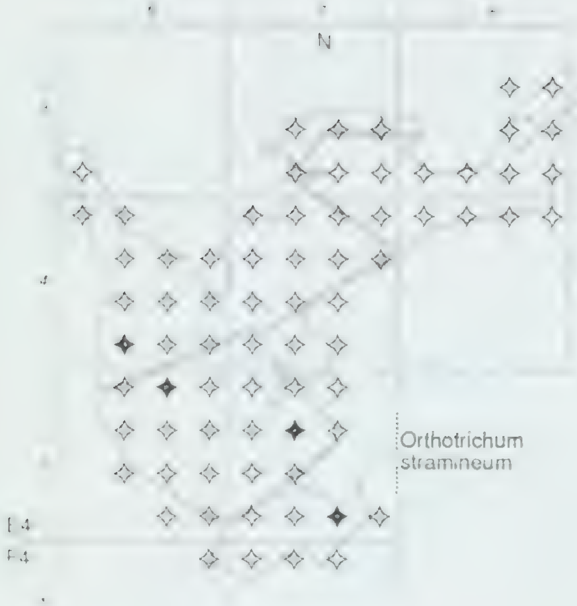
Orthotrichum pallens



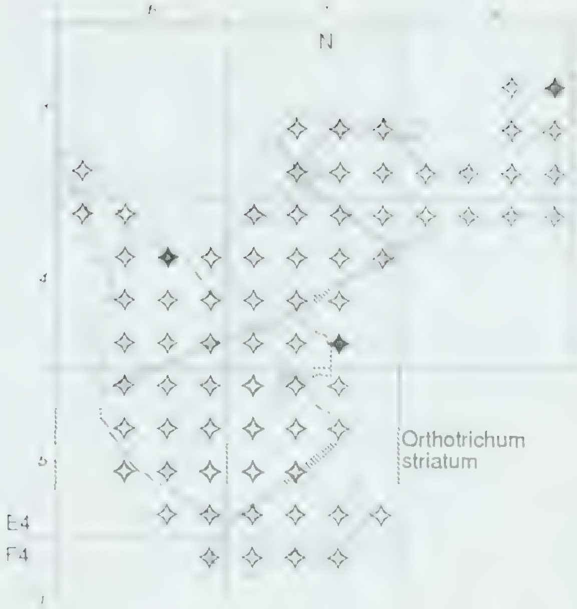
Orthotrichum pulchellum



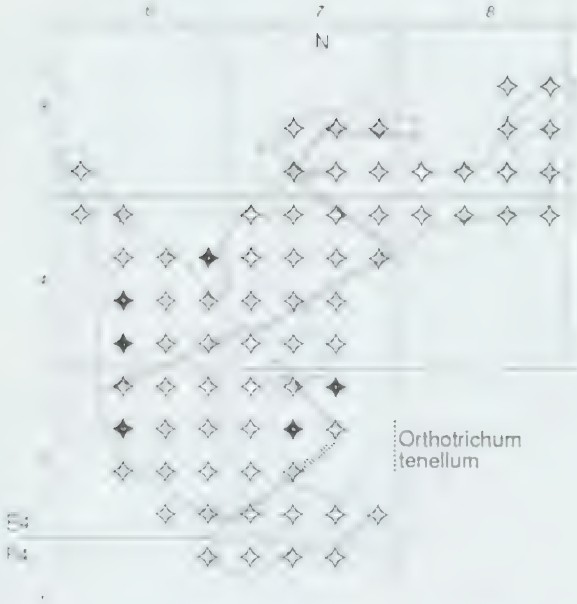
Orthotrichum pumilum



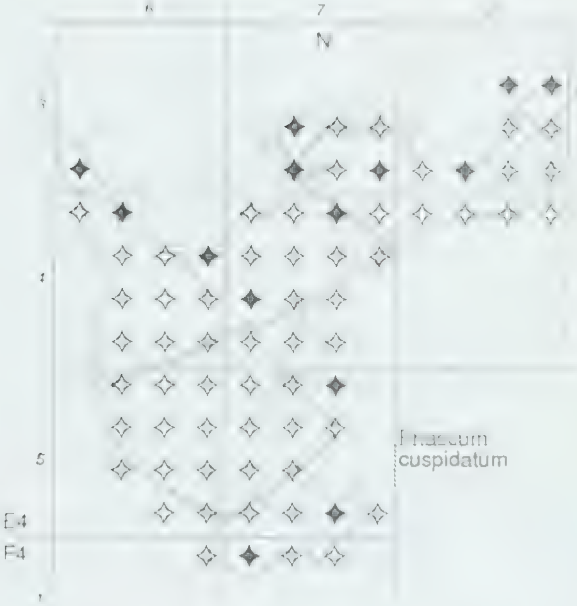
Orthotrichum stramineum



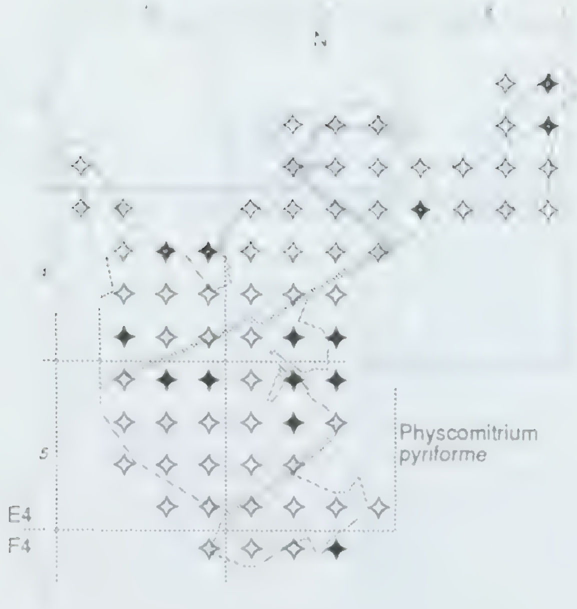
Orthotrichum striatum



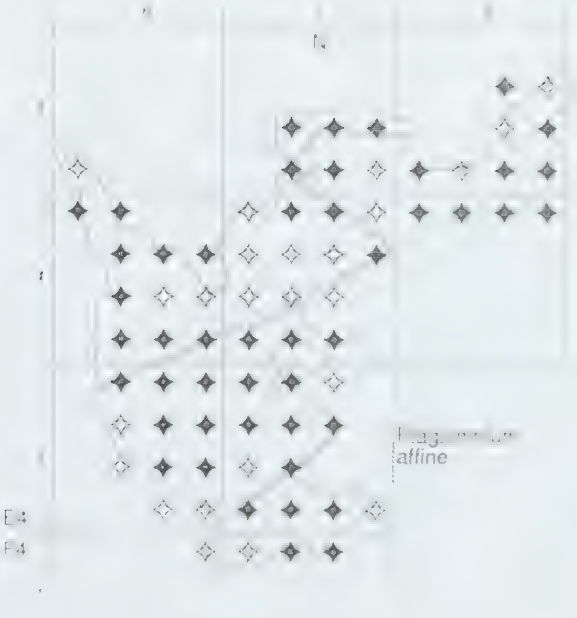
Orthotrichum tenellum



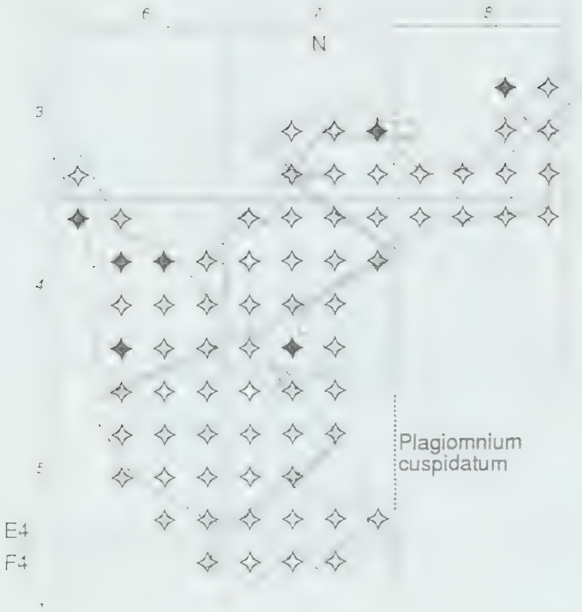
Phascum cuspidatum



Physcomitrium pyriforme



Plagiomnium affine



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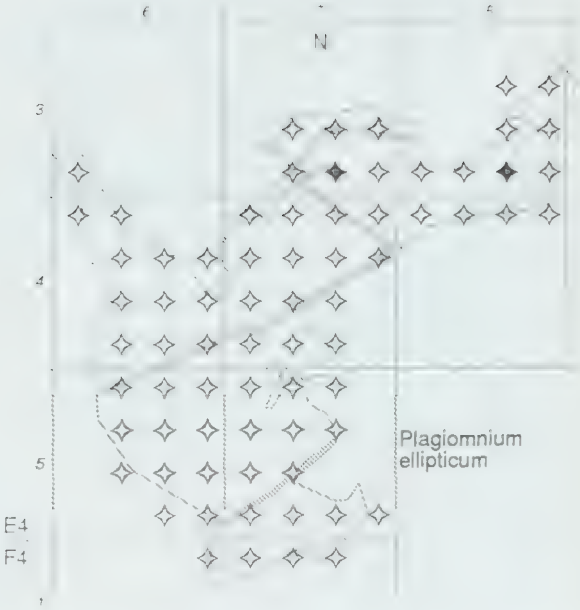
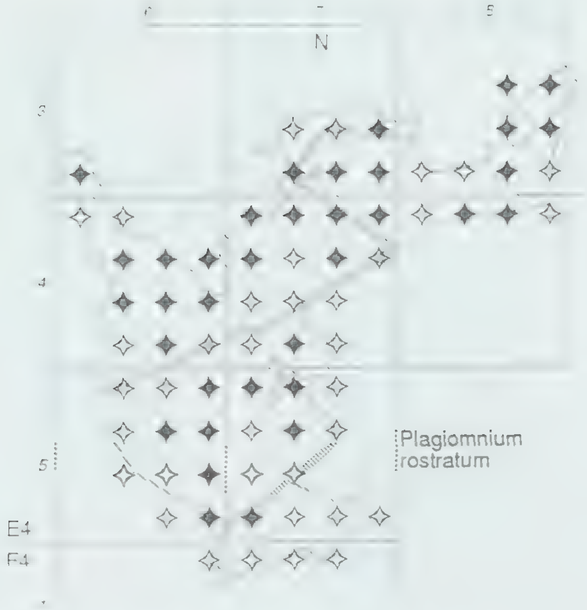
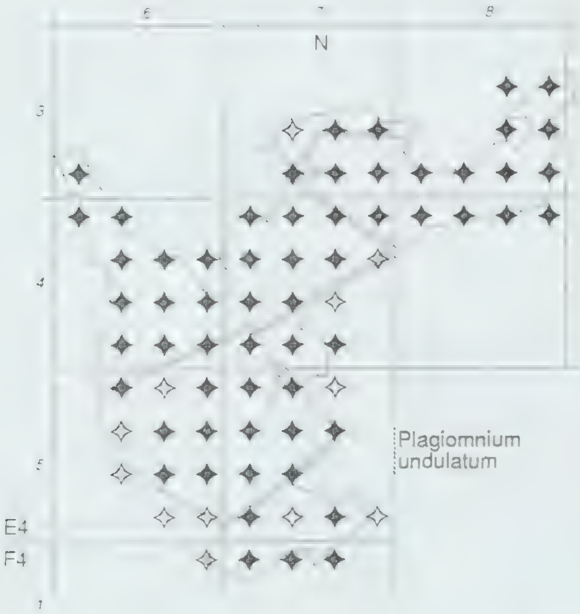


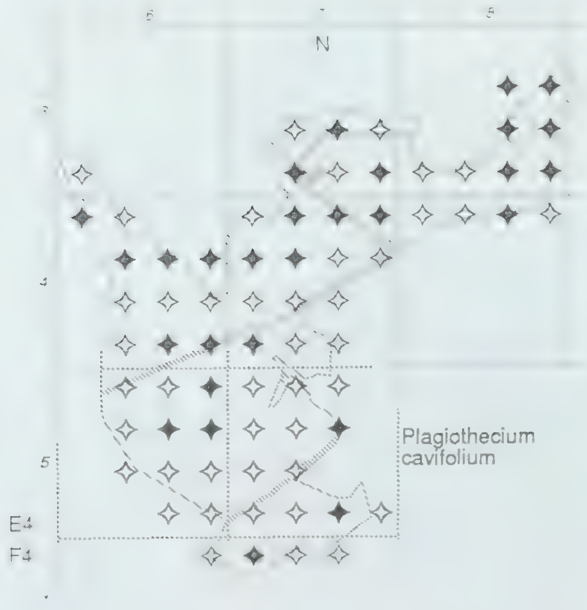
Plagiomnium ellipticum



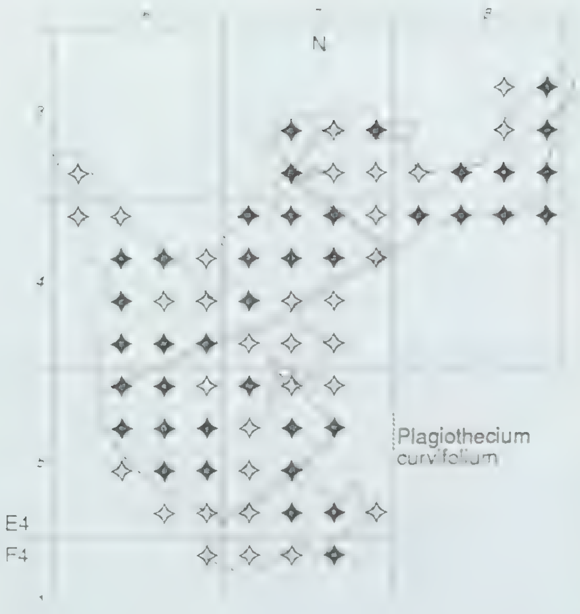
Plagiomnium rostratum



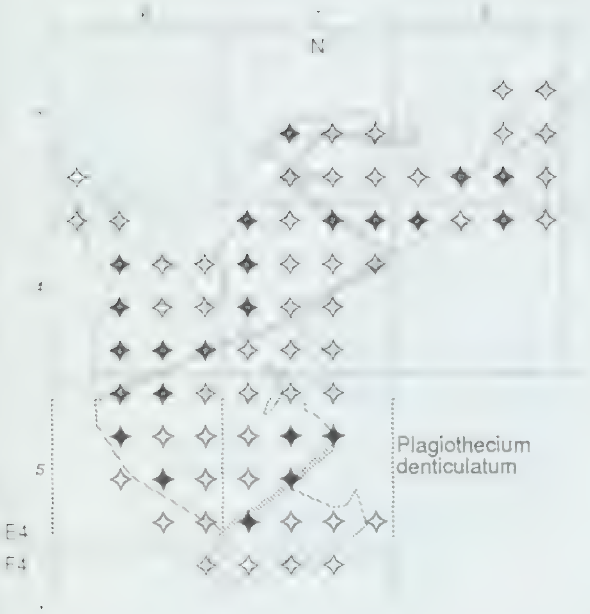
Plagiomnium undulatum



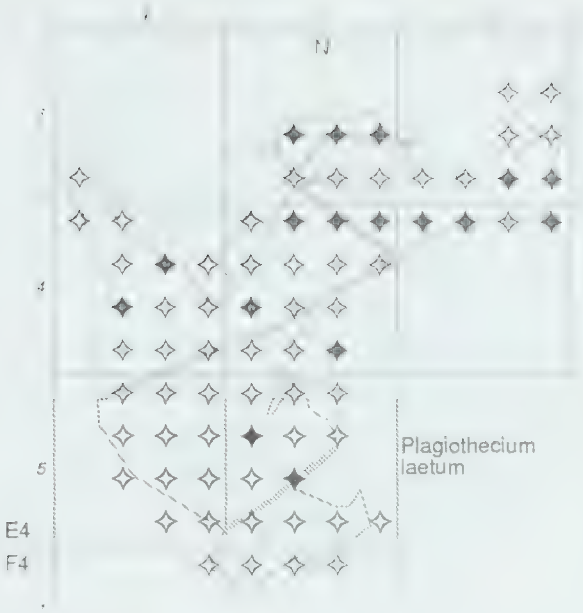
Plagiothecium cavifolium



Plagiothecium curvifolium



Plagiothecium denticulatum



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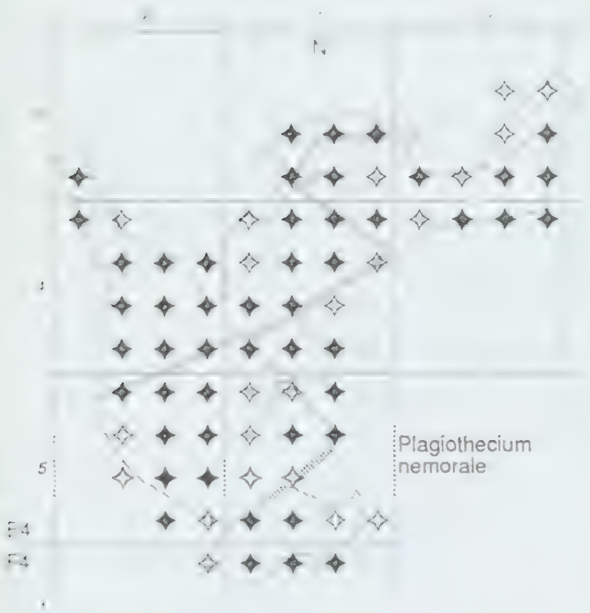
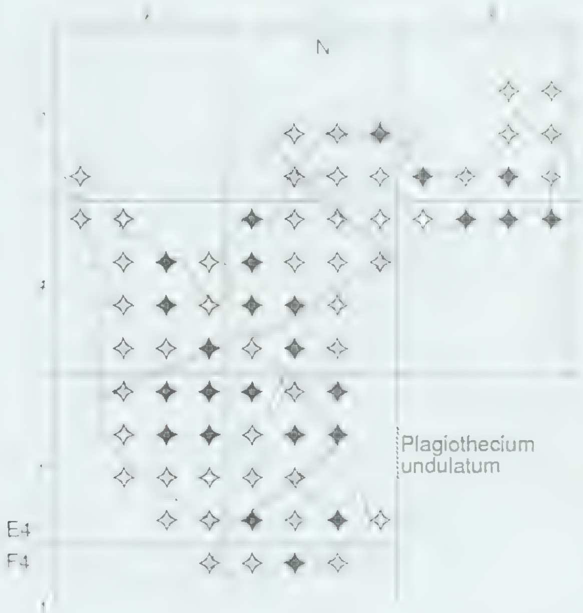
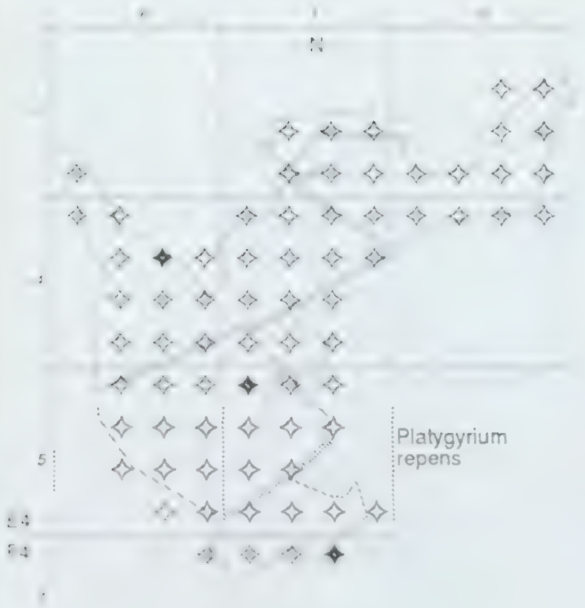


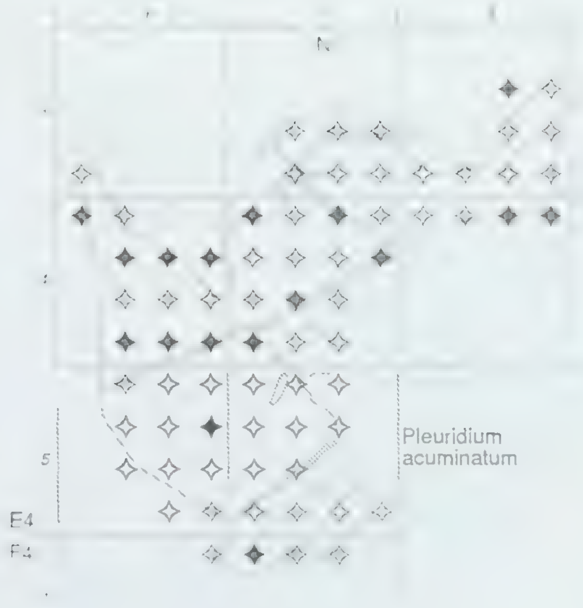
Plagiothecium nemorale



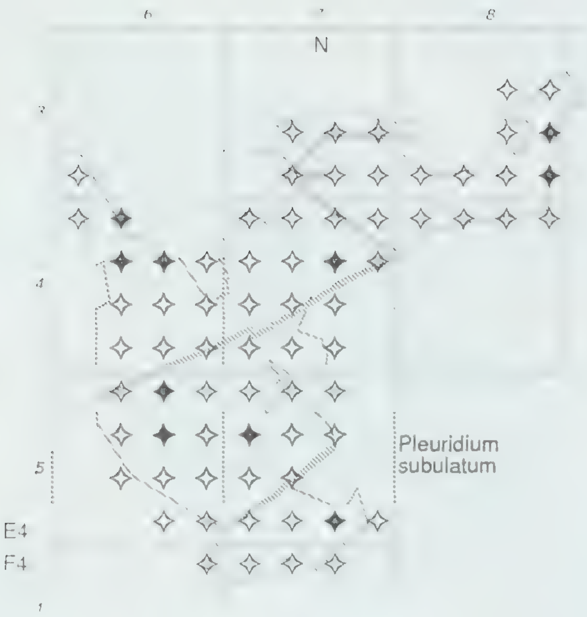
Plagiothecium undulatum



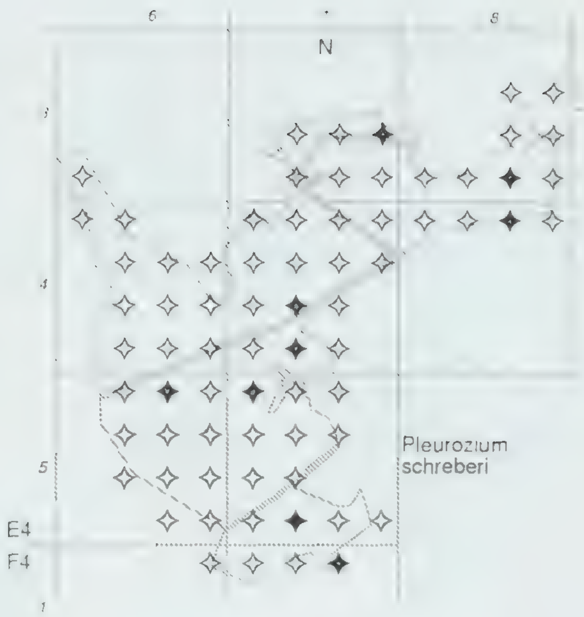
Platygyrium repens



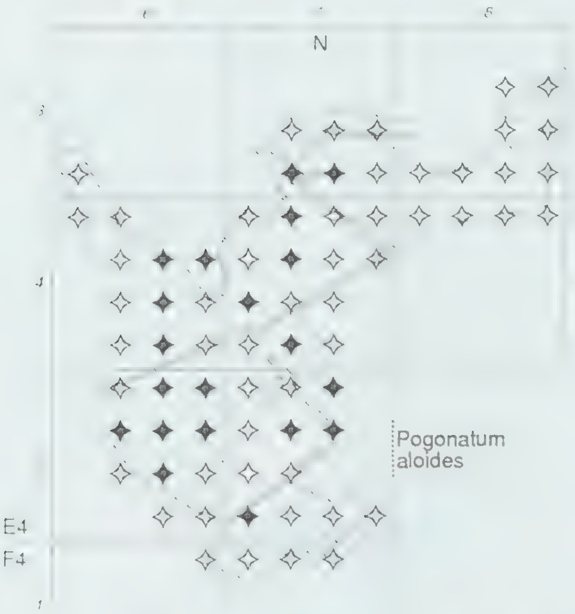
Pleuridium acuminatum



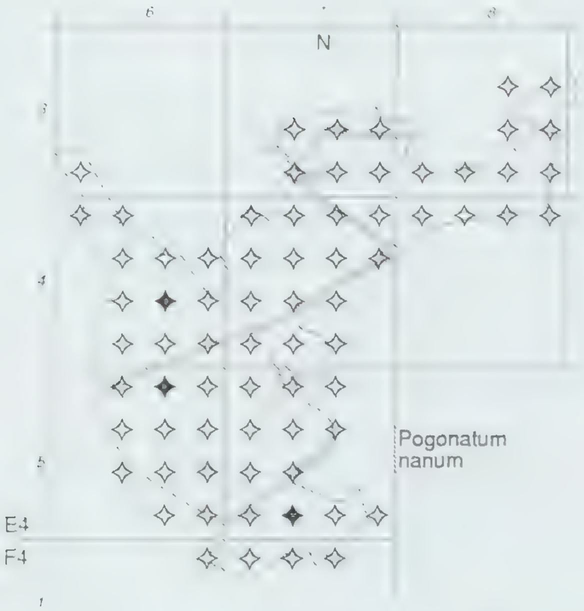
Pleuridium subulatum



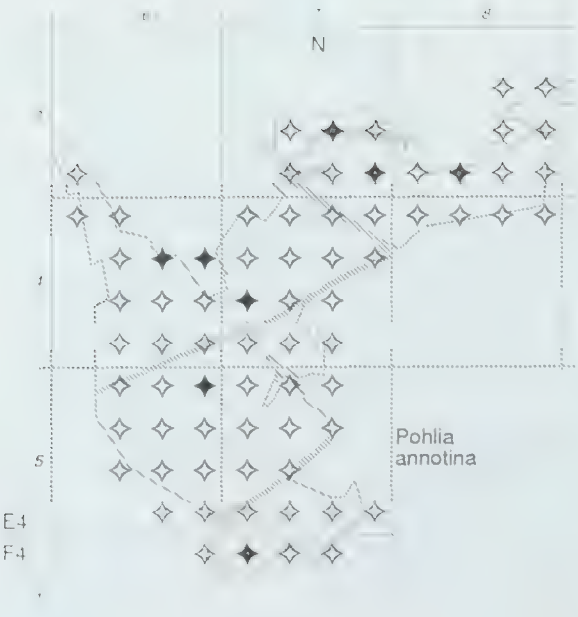
Pleurozium schreberi



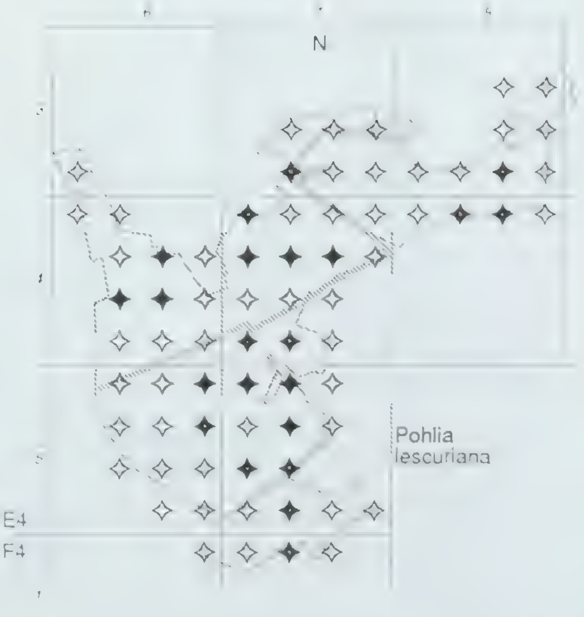
Pogonatum aloides



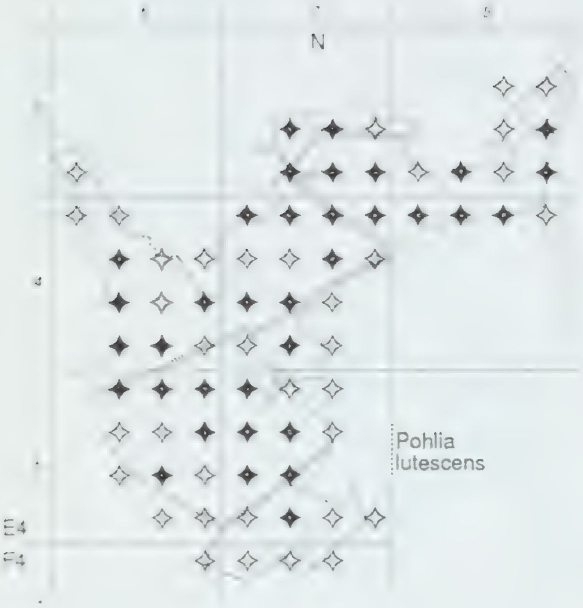
Pogonatum nanum



Pohlia annotina



Pohlia lescuriana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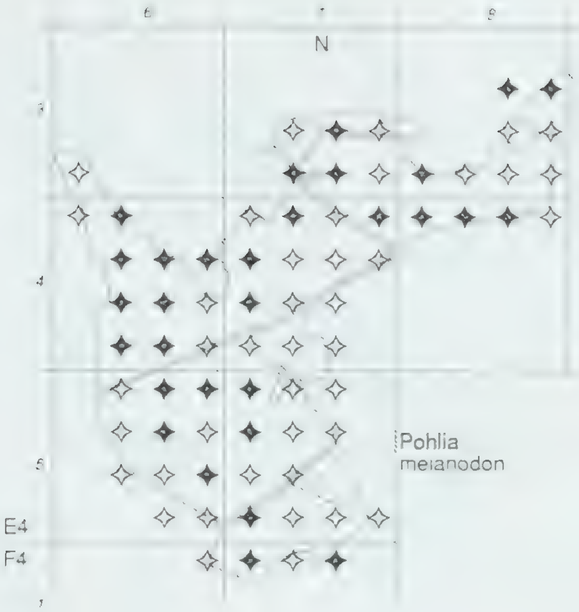
F4
Pohlia lutescens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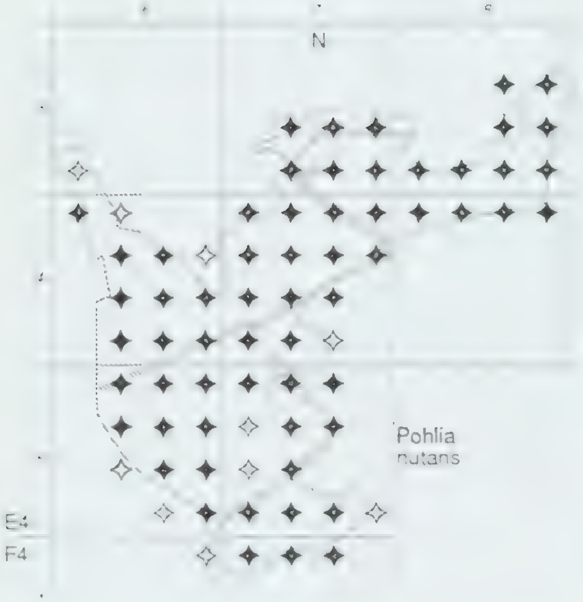
Pohlia melanodon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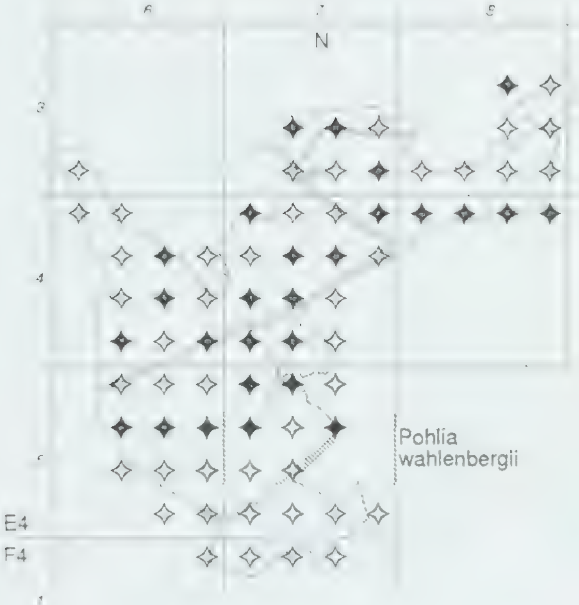
Pohlia nutans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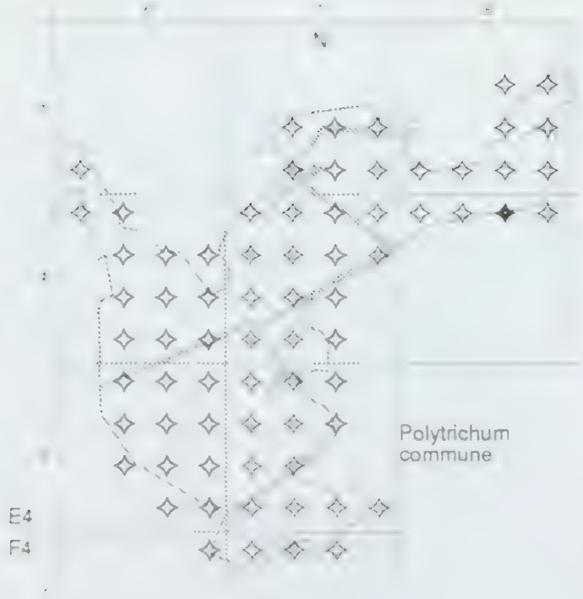
Pohlia wahlenbergii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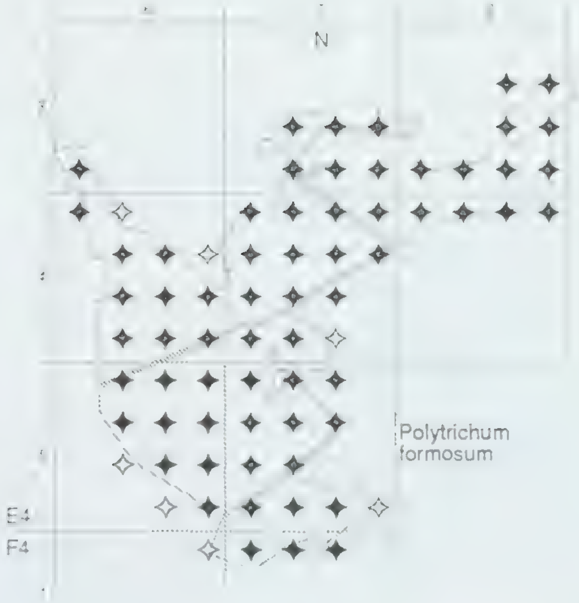
Polytrichum commune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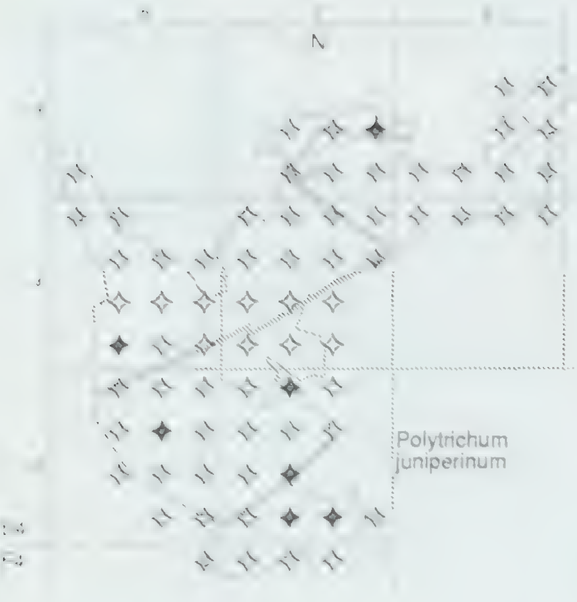
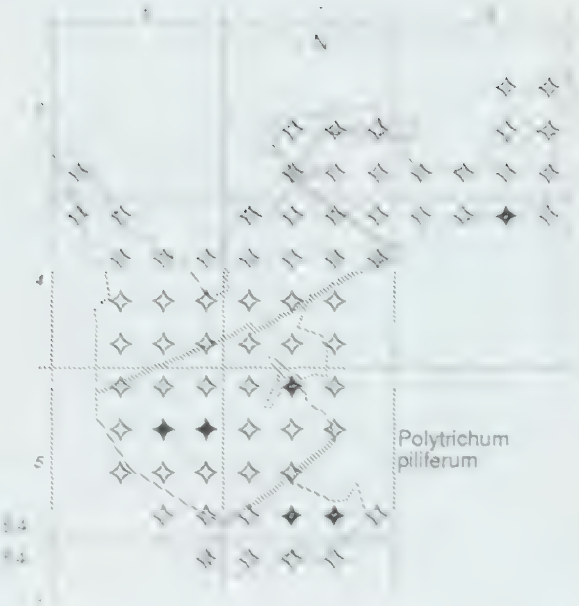
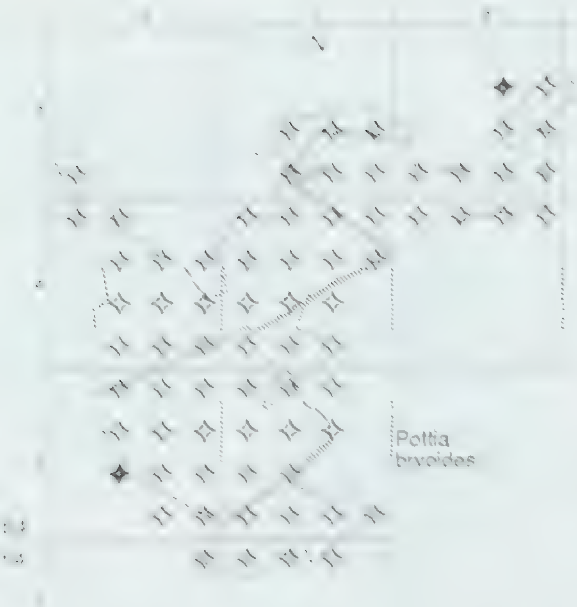
Polytrichum formosum



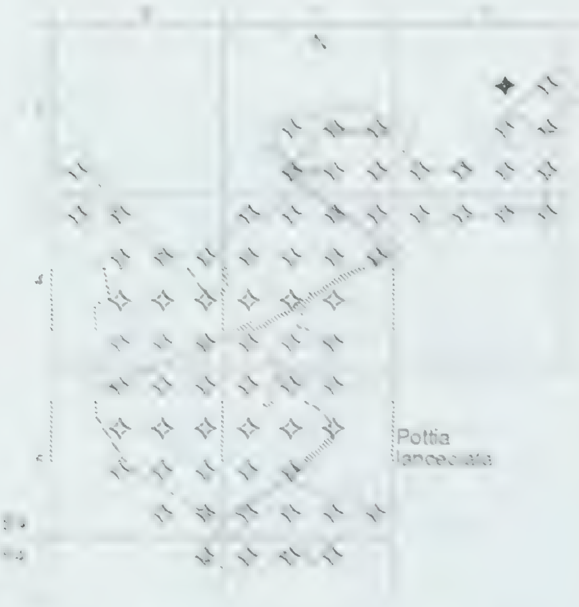
Polytrichum juniperinum



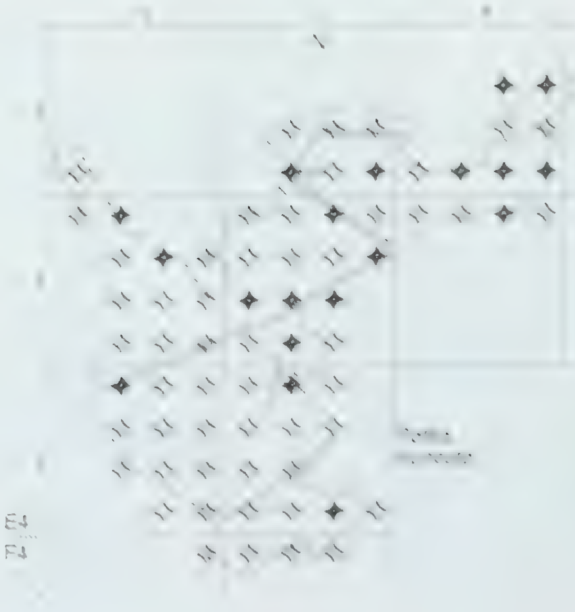
Polytrichum piliferum



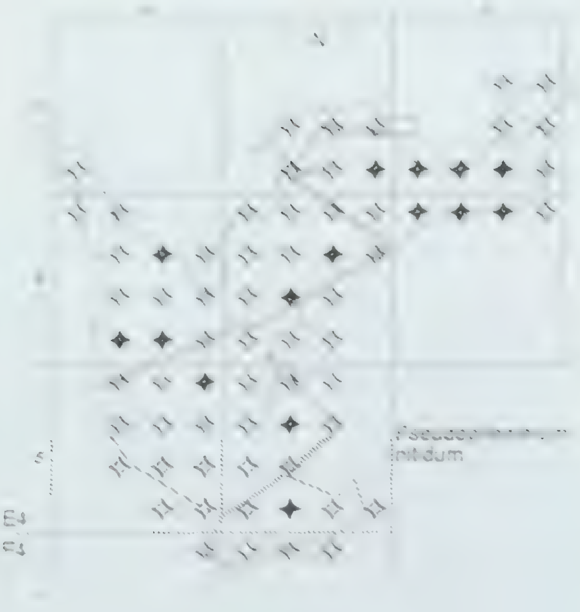
Pottia bryoides



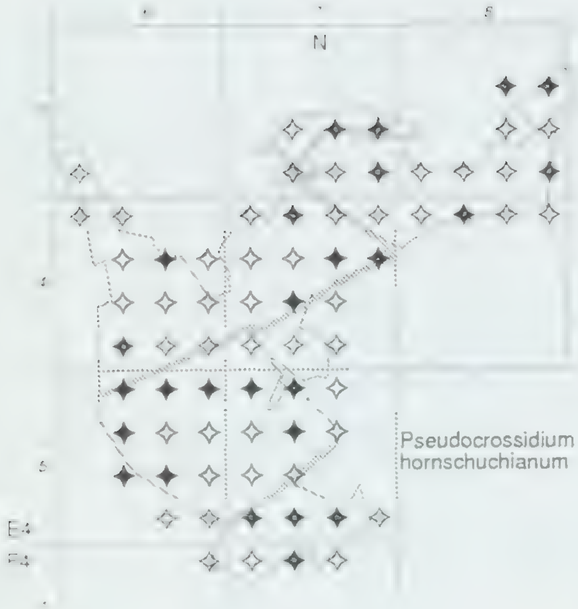
Pottia lanceolata



Pottia [illegible]



Pseud[illegible]
nitidum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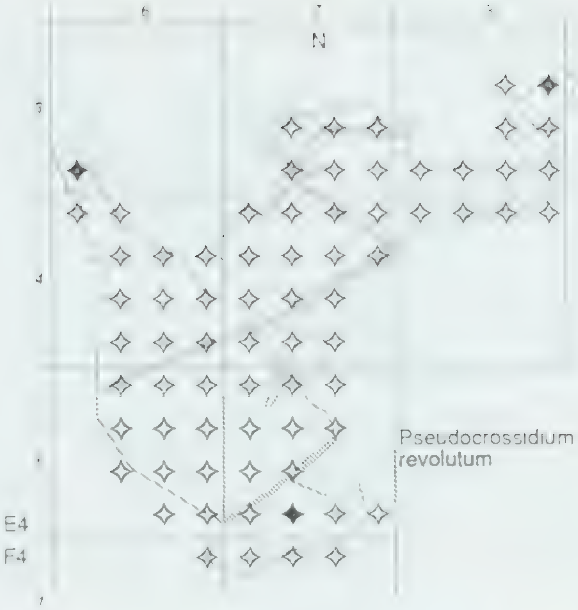
F4
Pseudocrossidium hornschuchianum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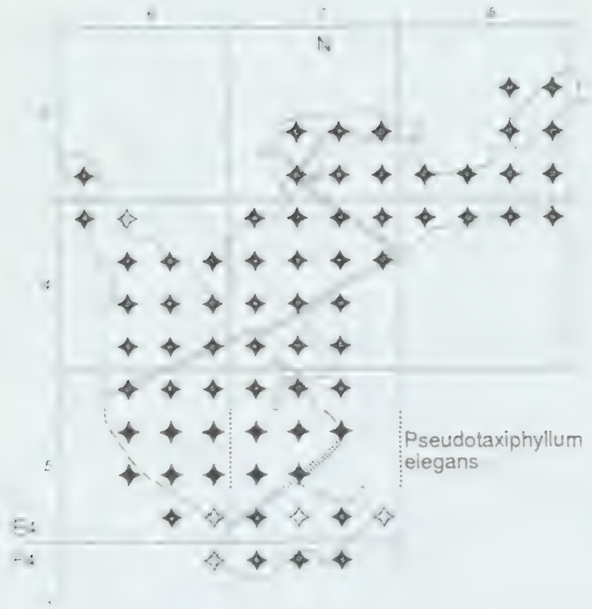
Pseudocrossidium revolutum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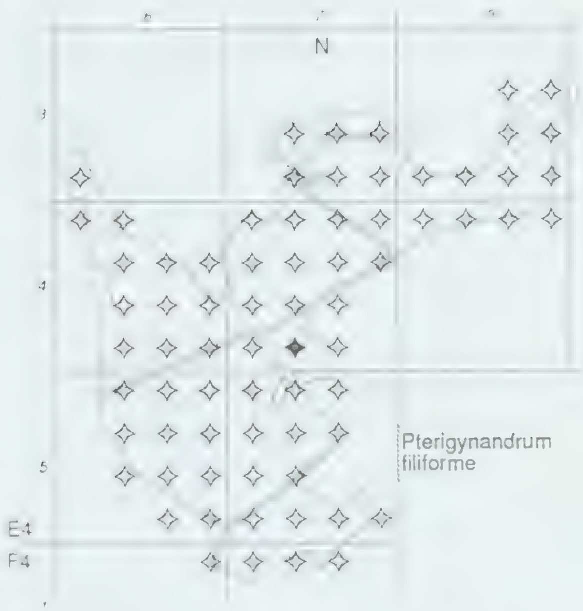
Pseudotaxiphyllum elegans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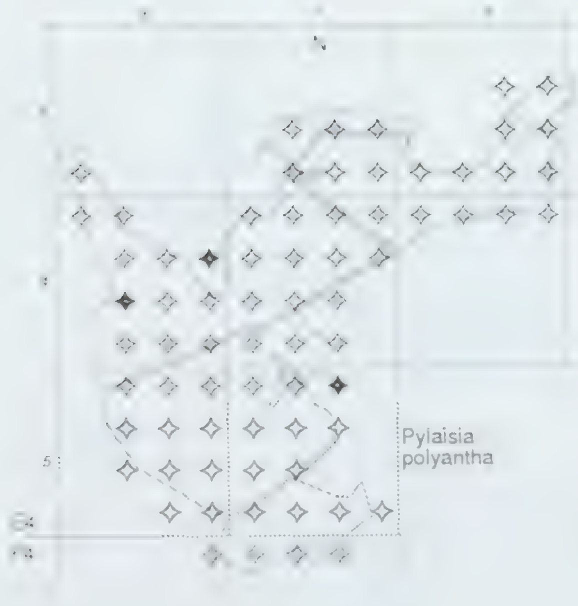
Pterigynandrum filiforme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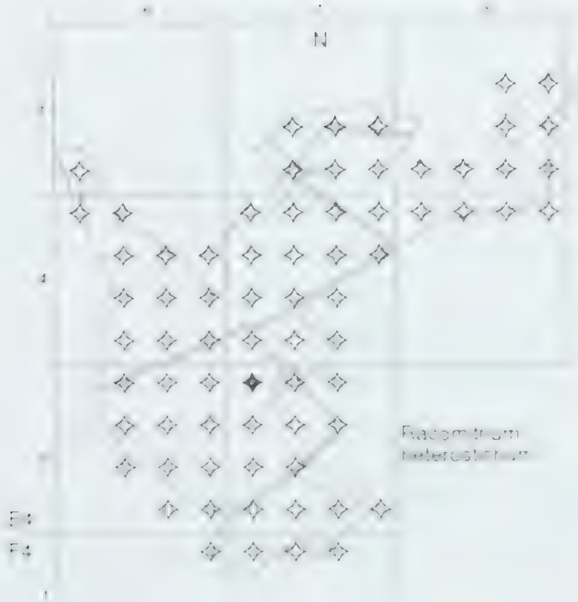
Pylaisia polyantha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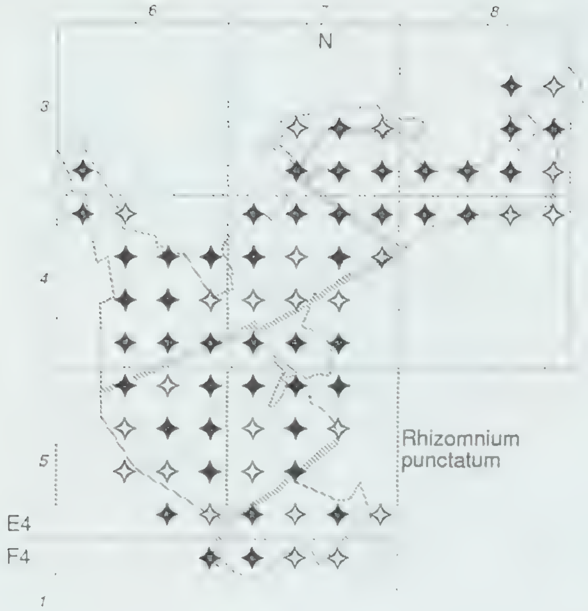
Racomitrium heterostichum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E4
F4
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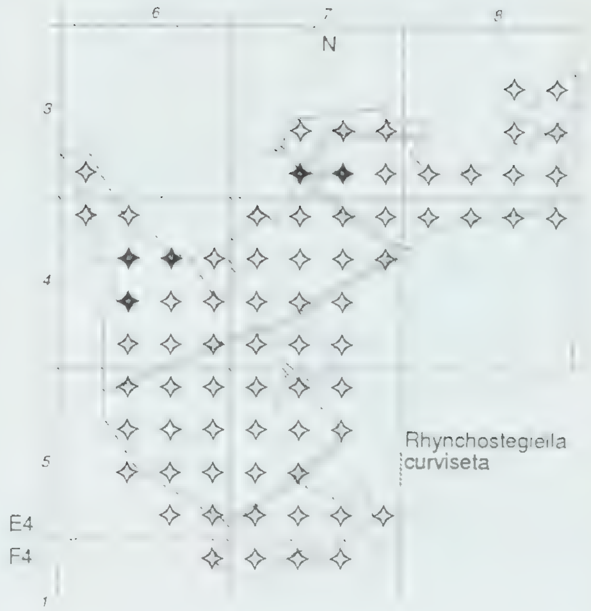
Rhizomnium punctatum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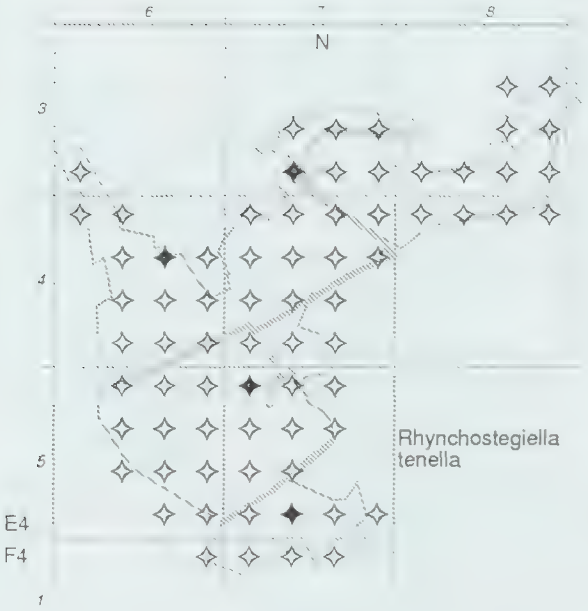
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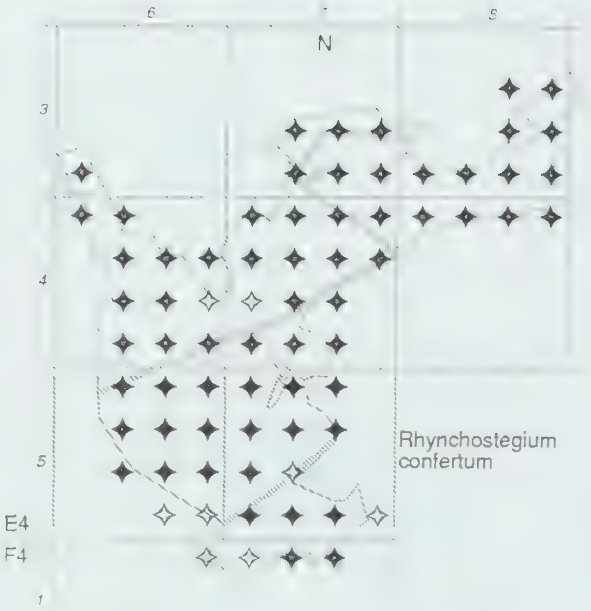
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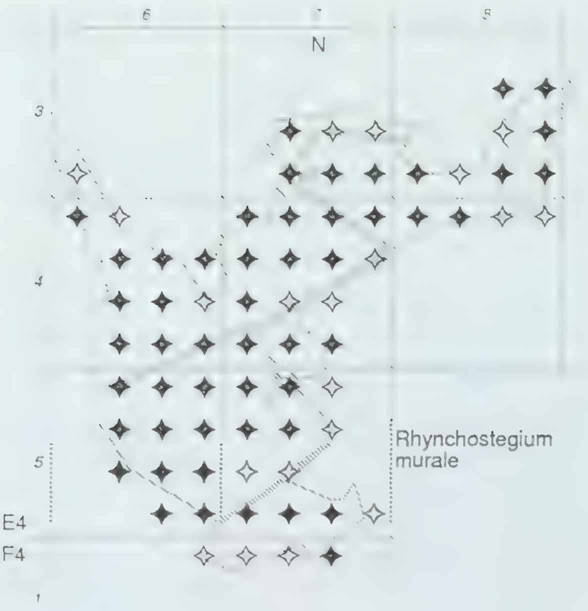
Rhynchostegium confertum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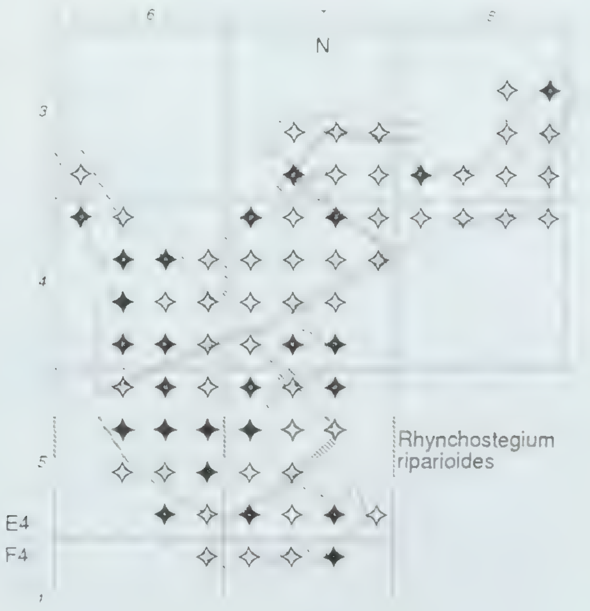
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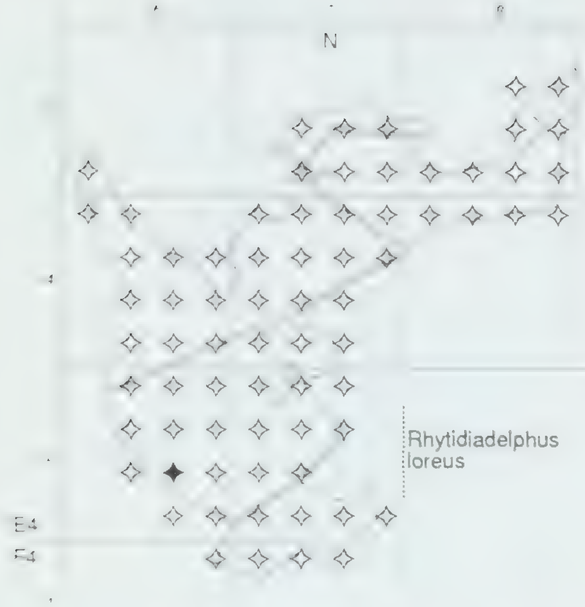
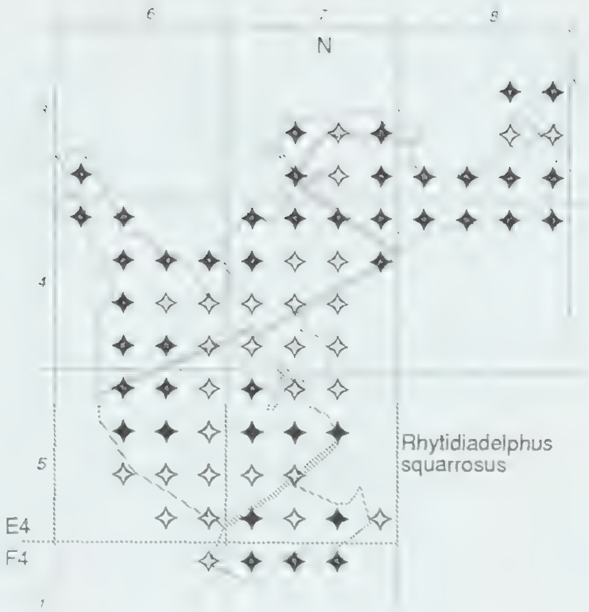


Rhytidiadelphus loreus



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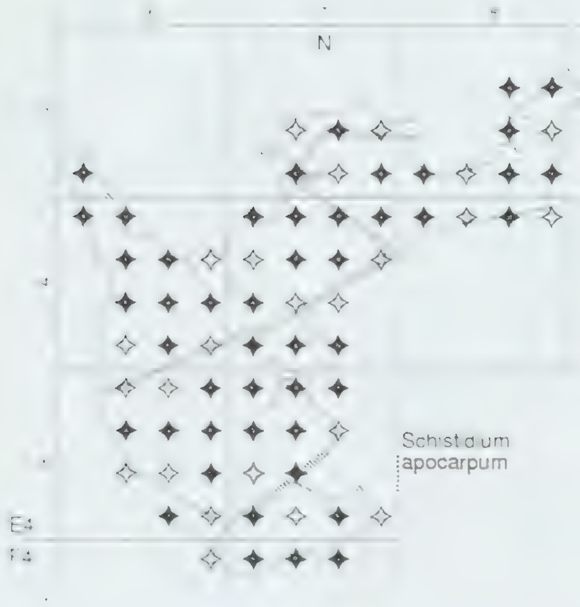

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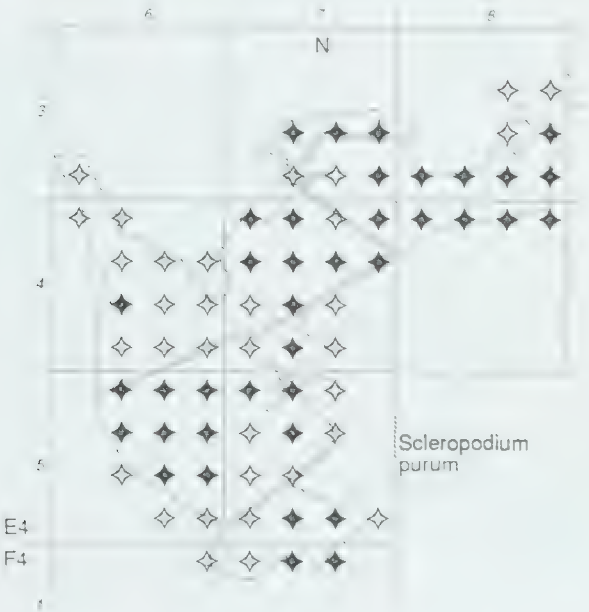

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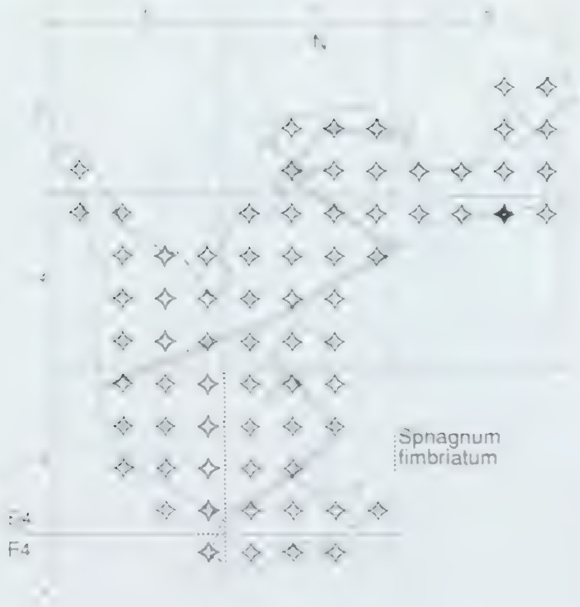

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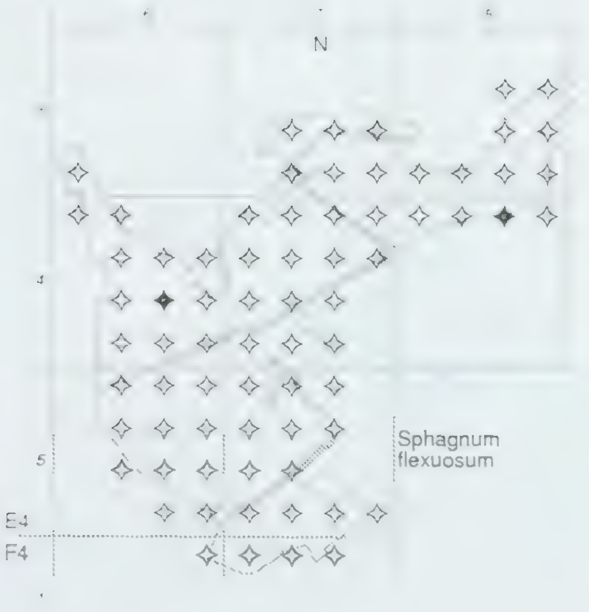

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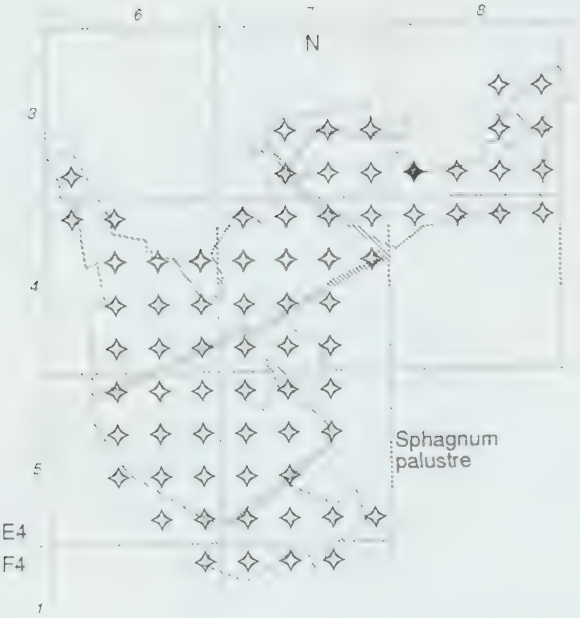

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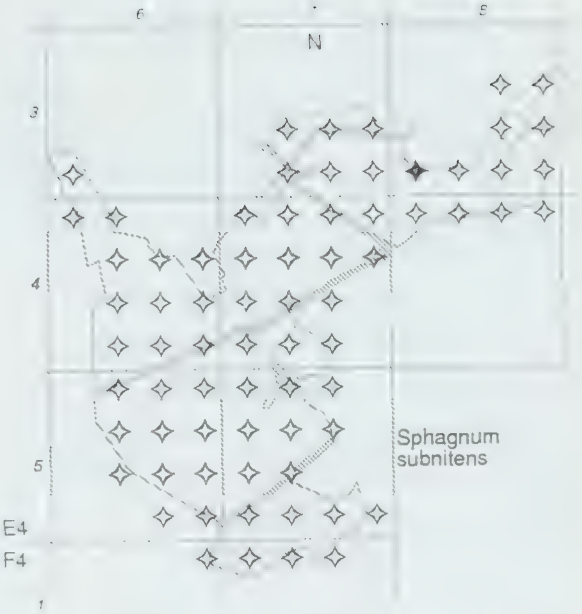

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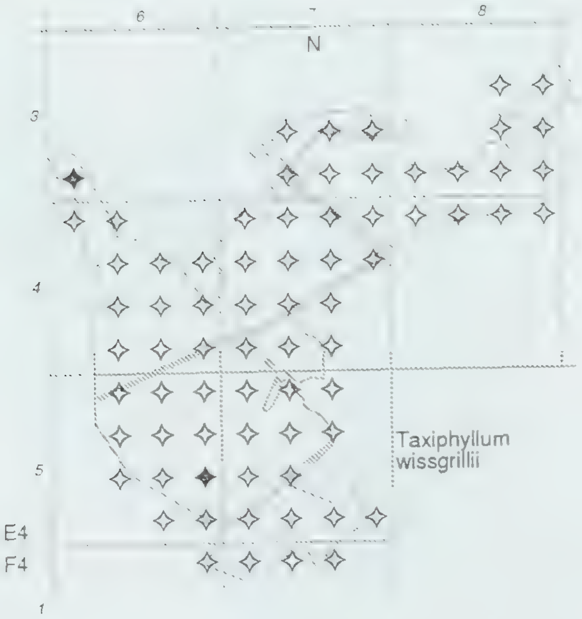

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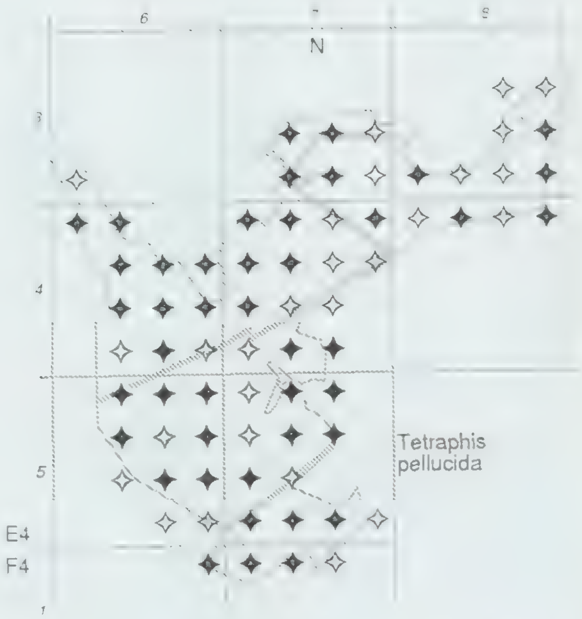

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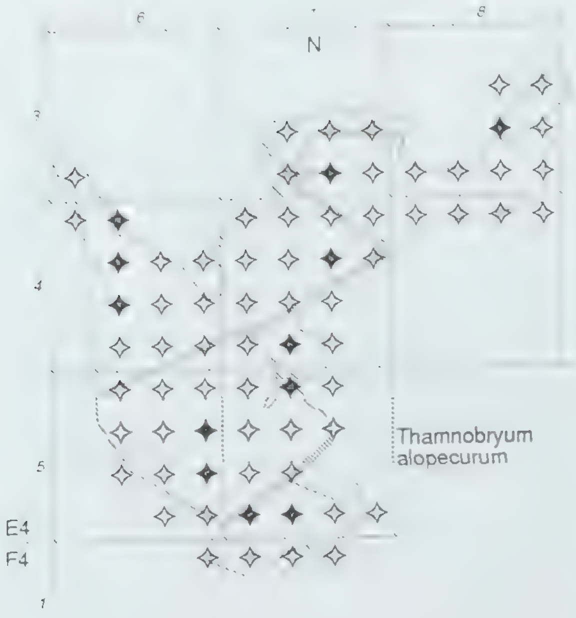

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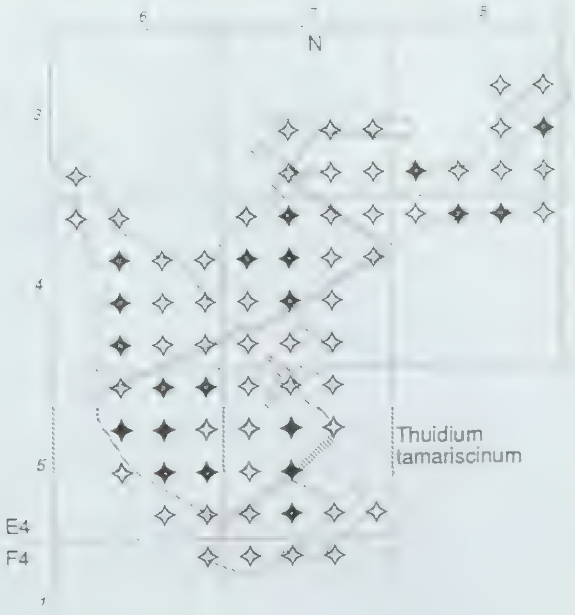
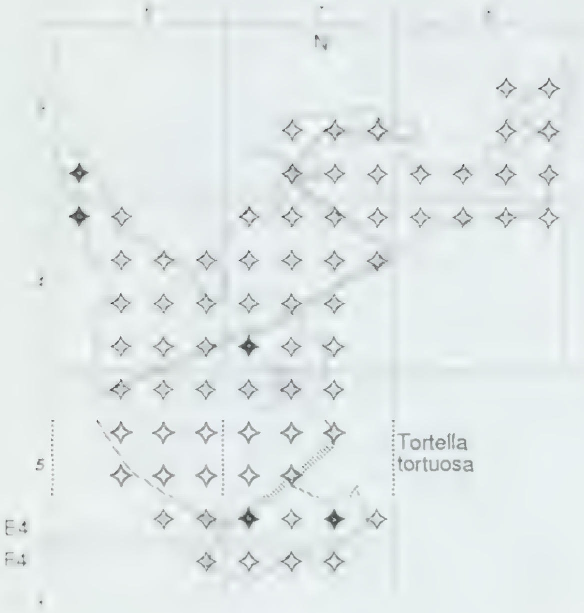
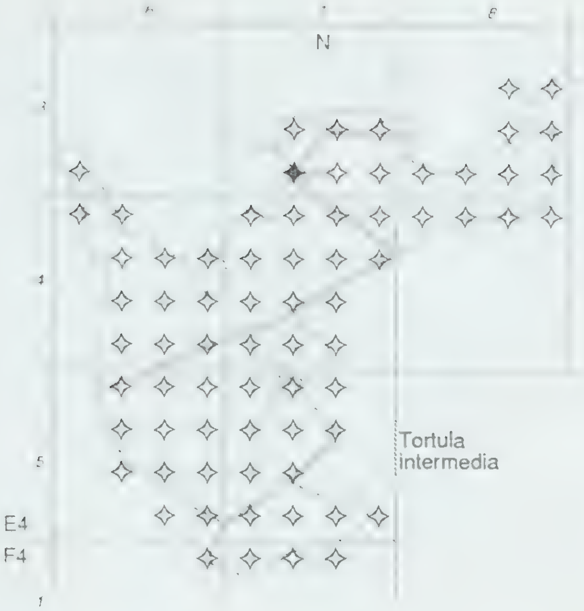


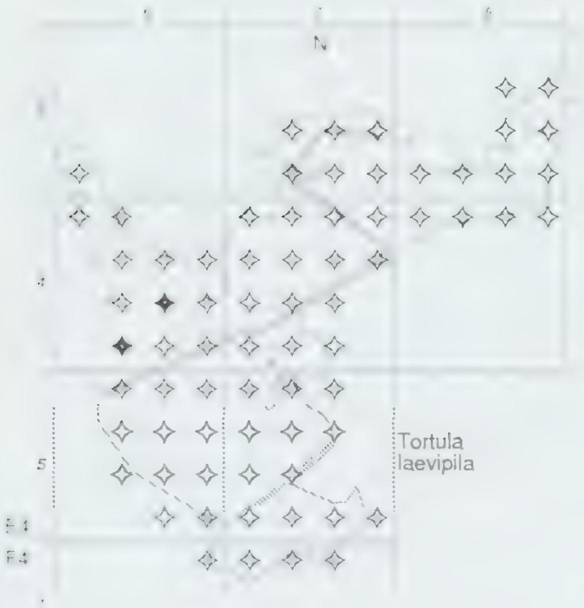
Thuidium tamariscinum



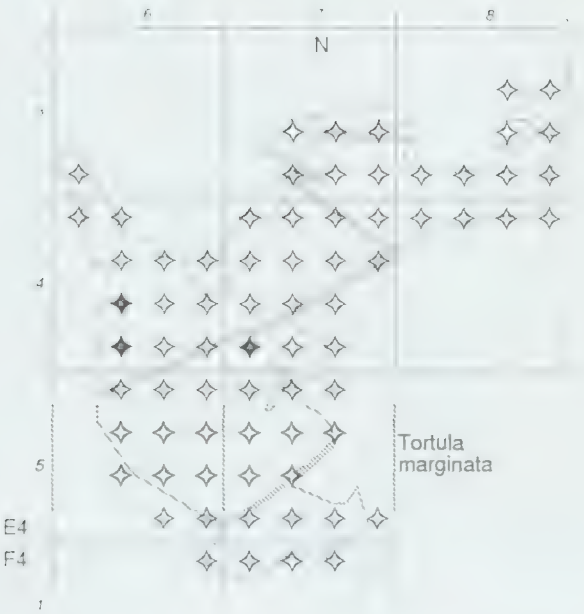
Tortella tortuosa



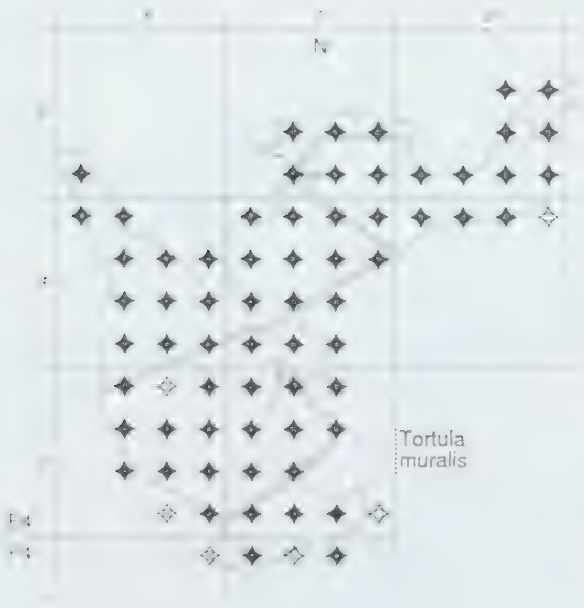
Tortula intermedia



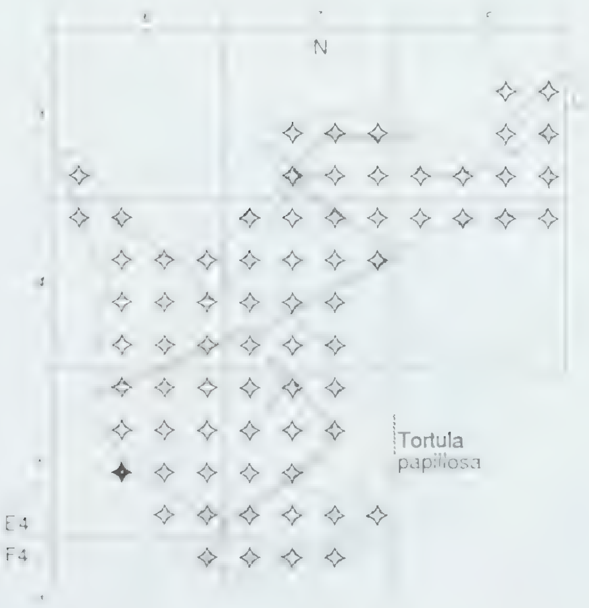
Tortula laevipila



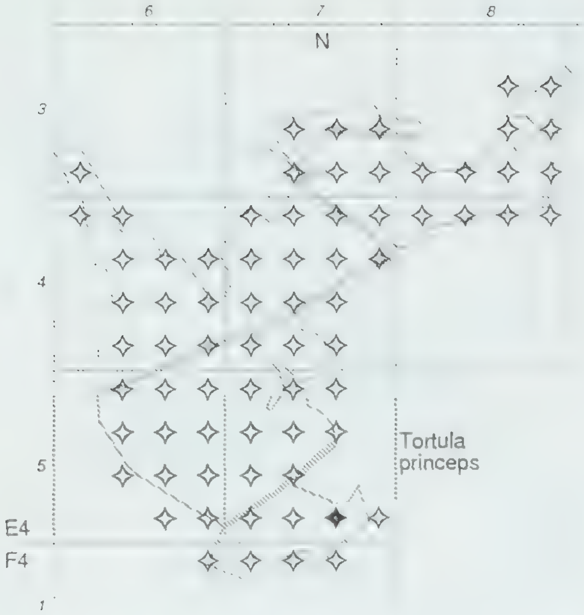
Tortula marginata



Tortula muralis



Tortula papillosa



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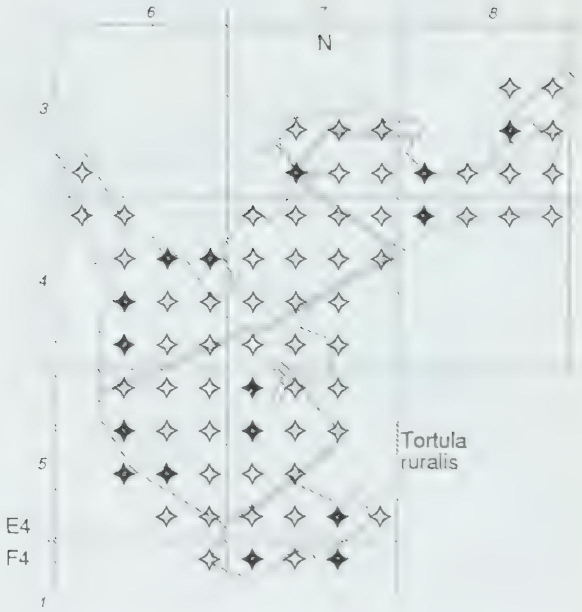
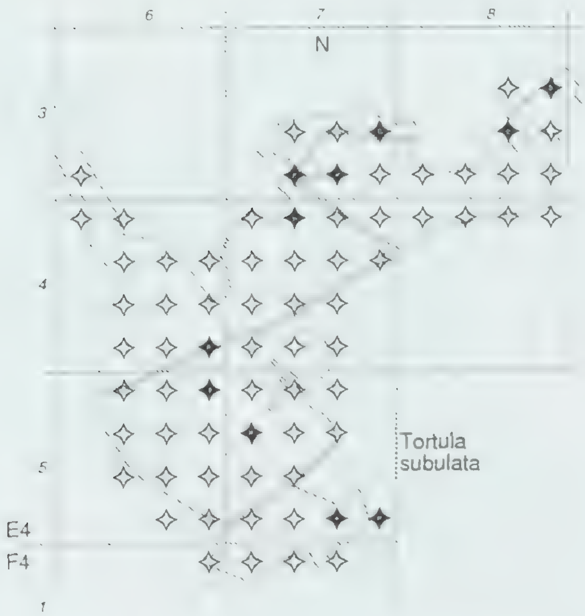
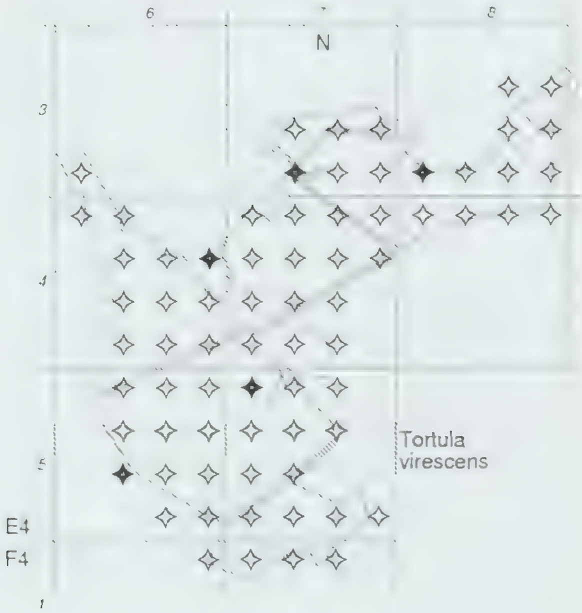


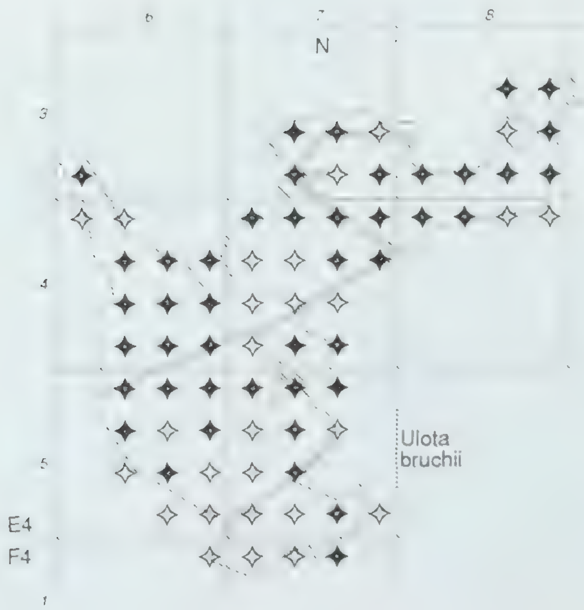
Tortula ruralis



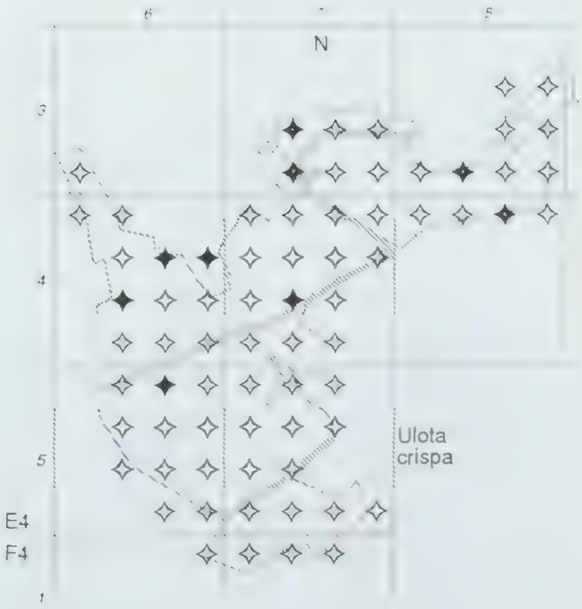
Tortula subulata



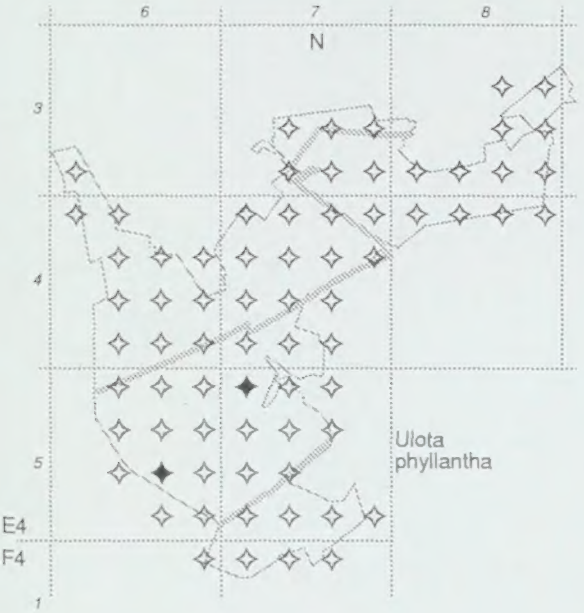
Tortula virescens



Ulota bruchii



Ulota crispa



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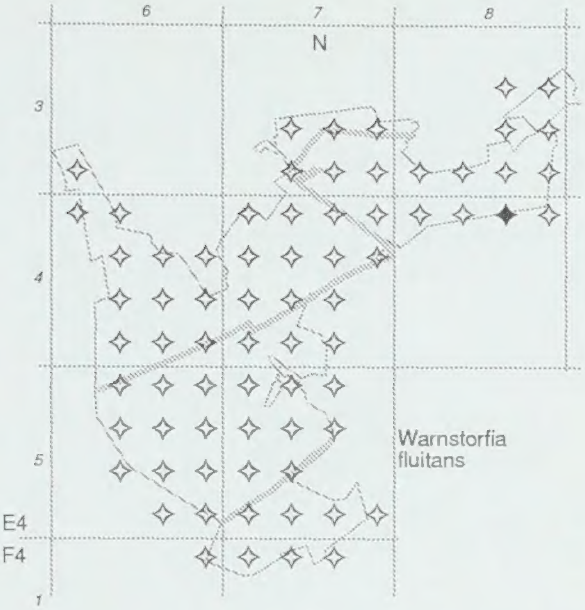
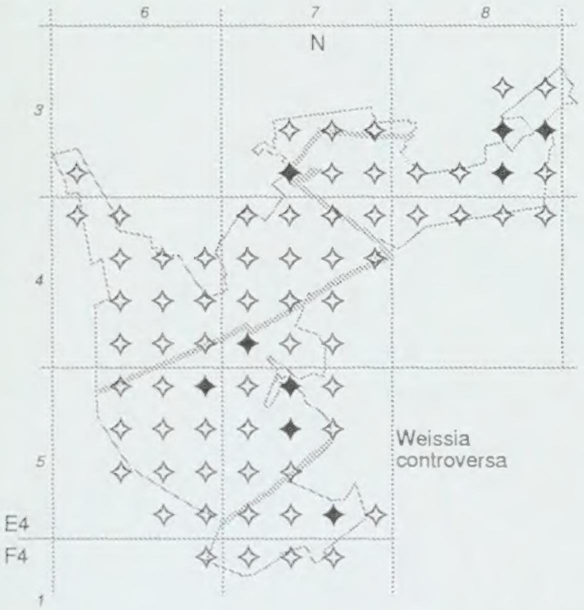
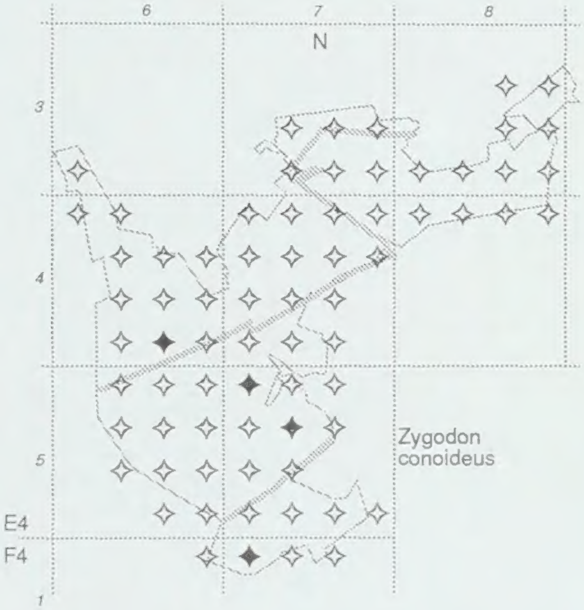


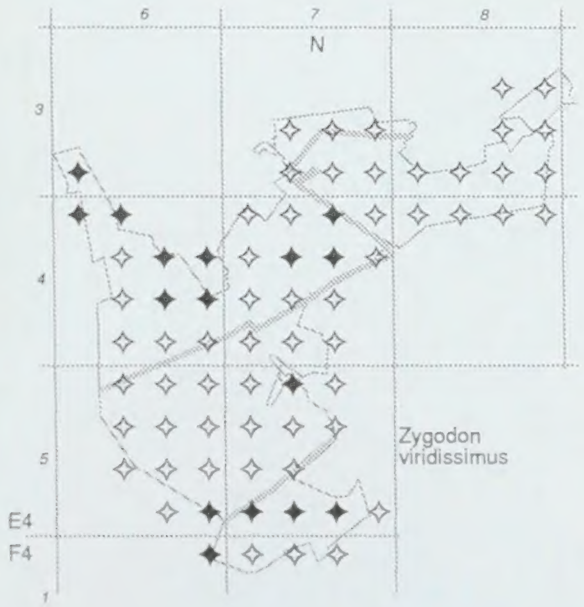
Warnstorfia fluitans



Weissia controversa



Zygodon conoideus



Zygodon viridissimus

Scripta Botanica Belgica **18**

THE DISTRIBUTION OF BRYOPHYTES IN THE FOREST OF SOIGNES (SOUTH OF BRUSSELS, BELGIUM)

A. Sotiaux
O. Sotiaux
A. Vanderpoorten
L. Durwael
(coll. A. Empain)

In the present book, a detailed inventory is presented of the flora of a large forest (71 km^2) just south of the connurbation of the Brussels Capital Region. It is based on field observations of the authors from 1980 to 1998. Grid maps are presented for the 257 bryophytes found during the survey. The data are used to list the hot spots with highest bryo-diversity. The authors propose management measures to preserve the conservation value of the forest.

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